

1 **HIGH POWER UMBILICALS FOR ELECTRIC FLOWLINE**
2 **IMMERSION HEATING OF PRODUCED HYDROCARBONS**

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6 **PRIORITY FROM U.S. PATENT APPLICATION**

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8 The present application is a continuation-in-part
9 (C.I.P) application of co-pending U.S. Patent Application
10 Serial No. 10/223,025, filed August 15, 2002, that is
11 entitled "High Power Umbilicals for Subterranean Electric
12 Drilling Machines and Remotely Operated Vehicles", an
13 entire copy of which is incorporated herein by reference.
14 Serial No. 10/223,025 was published on February 20, 2003,
15 having Publication Number US 2003/0034177 A1.

16

17 Applicant claims priority from U.S. Patent Application
18 Serial No. 10/223,025.

19

20

21 **PRIORITY FROM U.S. PROVISIONAL PATENT APPLICATIONS**

22

23 The present application relates to Provisional Patent
24 Application Number 60/432,045, filed on December 8, 2002,
25 that is entitled "Pump Down Cement Float Valves for Casing
26 Drilling, Pump Down Electrical Umbilicals, and Subterranean
27 Electric Drilling Systems", an entire copy of which is
28 incorporated herein by reference.

29

30 The present application also relates to Provisional
31 Patent Application Number 60/448,191, filed on February 18,
32 2003, that is entitled "Long Immersion Heater Systems",
33 an entire copy of which is incorporated herein by reference.

34

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1 The present application also relates to Provisional
2 Patent Application Number 60/455,657, filed on March 18,
3 2003, that is entitled "Four SDCI Application Notes
4 Concerning Subsea Umbilicals and Construction Systems",
5 an entire copy of which is incorporated herein by reference.

The present application also relates to Provisional Patent Application Number 60/504,359, filed on September 20, 2003, that is entitled "Additional Disclosure on Long Immersion Heater Systems", an entire copy of which is incorporated herein by reference.

13 And finally, the present application also relates to
14 Provisional Patent Application Number 60/523,894, filed on
15 November 20, 2003, that is entitled "More Disclosure on Long
16 Immersion Heater Systems", an entire copy of which is
17 incorporated herein by reference.

19 Applicant claims priority from the above U.S.
20 Provisional Patent Applications No. 60/432,045,
21 No. 60/448,191, No. 60/455,657, No. 60/504,359, and
22 No. 60/523,894.

CROSS-REFERENCES TO RELATED APPLICATIONS

26 This application relates to Provisional Patent
27 Application Number 60/313,654 filed on August 19, 2001,
28 that is entitled "Smart Shuttle Systems", an entire copy of
29 which is incorporated herein by reference.

31 This application also relates to Provisional Patent
32 Application Number 60/353,457 filed on January 31, 2002, that
33 is entitled "Additional Smart Shuttle Systems", an entire
34 copy of which is incorporated herein by reference.

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1 This application further relates to Provisional Patent
2 Application Number 60/367,638 filed on March 26, 2002, that
3 is entitled "Smart Shuttle Systems and Drilling Systems", an
4 entire copy of which is incorporated herein by reference.

5
6 And yet further, this application also relates the
7 Provisional Patent Application Number 60/384,964 filed on
8 June 3, 2002, that is entitled "Umbilicals for Well
9 Conveyance Systems and Additional Smart Shuttles and Related
10 Drilling Systems", an entire copy of which is incorporated
11 herein by reference.

12
13 Serial No. 10/223,025 claimed priority from the above
14 Provisional Patent Application No. 60/313,654,
15 No. 60/353,457, No. 60/367,638 and No. 60/384,964, and
16 applicant claims any relevant priority in the present
17 application.

18
19 The following applications are related to this
20 application, but applicant does not claim priority from the
21 following related applications.

22
23 This application relates to Serial No. 09/375,479, filed
24 August 16, 1999, having the title of "Smart Shuttles to
25 Complete Oil and Gas Wells", that issued on February 20,
26 2001, as U.S. Patent No. 6,189,621 B1, an entire copy of
27 which is incorporated herein by reference.

28
29 This application also relates to application Serial
30 No. 09/487,197, filed January 19, 2000, having the title of
31 "Closed-Loop System to Complete Oil and Gas Wells", that
32 issued on June 4, 2002 as U.S. Patent No. 6,397,946 B1,
33 an entire copy of which is incorporated herein by reference.

34

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1 This application also relates to co-pending application
2 Serial No. 10/162,302, filed June 4, 2002, having the title
3 of "Closed-Loop Conveyance Systems for Well Servicing", an
4 entire copy of which is incorporated herein by reference.

5

6

7 Related PCT Applications

8

9 And yet further, this application also relates to
10 co-pending PCT Application Serial Number PCT/US00/22095,
11 filed August 9, 2000, having the title of "Smart Shuttles to
12 Complete Oil and Gas Wells", that has International
13 Publication Date of February 22, 2001 and International
14 Publication Number WO 01/12946 A1, an entire copy of which
15 is incorporated herein by reference.

16

17 This application further relates to PCT Patent
18 Application Number PCT/US02/26066 filed on August 16, 2002,
19 entitled "High Power Umbilicals for Subterranean Electric
20 Drilling Machines and Remotely Operated Vehicles", that
21 has International Publication Date of February 27, 2003,
22 and has the International Publication Number WO 03/016671 A2.

23

24

25 Related U.S. Disclosure Documents

26

27 This application further relates to disclosure in U.S.
28 Disclosure Document No. 451,044, filed on February 8, 1999,
29 that is entitled 'RE: -Invention Disclosure- "Drill Bit
30 Having Monitors and Controlled Actuators"', an entire copy of
31 which is incorporated herein by reference.

32

33 This application further relates to disclosure in U.S.
34 Disclosure Document No. 458,978 filed on July 13, 1999 that

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1 is entitled in part "RE: -INVENTION DISCLOSURE MAILED JULY
2 13, 1999", an entire copy of which is incorporated herein by
3 reference.

4

5 This application further relates to disclosure in U.S.
6 Disclosure Document No. 475,681 filed on June 17, 2000 that
7 is entitled in part "ROV Conveyed Smart Shuttle System
8 Deployed by Workover Ship for Subsea Well Completion and
9 Subsea Well Servicing", an entire copy of which is
10 incorporated herein by reference.

11

12 This application further relates to disclosure in U.S.
13 Disclosure Document No. 496,050 filed on June 25, 2001 that
14 is entitled in part "SDCI Drilling and Completion Patents and
15 Technology and SDCI Subsea Re-Entry Patents and Technology",
16 an entire copy of which is incorporated herein by reference.

17

18 This application further relates to disclosure in U.S.
19 Disclosure Document No. 480,550 filed on October 2, 2000
20 that is entitled in part "New Draft Figures for New Patent
21 Applications", an entire copy of which is incorporated herein
22 by reference.

23

24 This application further relates to disclosure in U.S.
25 Disclosure Document No. 493,141 filed on May 2, 2001 that is
26 entitled in part "Casing Boring Machine with Rotating Casing
27 to Prevent Sticking Using a Rotary Rig", an entire copy of
28 which is incorporated herein by reference.

29

30 This application further relates to disclosure in U.S.
31 Disclosure Document No. 492,112 filed on April 12, 2001 that
32 is entitled in part "Smart Shuttle™ Conveyed Drilling
33 Systems", an entire copy of which is incorporated herein by
34 reference.

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1 This application further relates to disclosure in U.S.
2 Disclosure Document No. 495,112 filed on June 11, 2001 that
3 is entitled in part "Liner/Drainhole Drilling Machine", an
4 entire copy of which is incorporated herein by reference.

5
6 This application further relates to disclosure in U.S.
7 Disclosure Document No. 494,374 filed on May 26, 2001 that is
8 entitled in part "Continuous Casting Boring Machine", an
9 entire copy of which is incorporated herein by reference.

10
11 This application further relates to disclosure in U.S.
12 Disclosure Document No. 495,111 filed on June 11, 2001 that
13 is entitled in part "Synchronous Motor Injector System", an
14 entire copy of which is incorporated herein by reference.

15
16 And yet further, this application also relates to
17 disclosure in U.S. Disclosure Document No. 497,719 filed on
18 July 27, 2001 that is entitled in part "Many Uses for The
19 Smart Shuttle™ and Well Locomotive™", an entire copy of which
20 is incorporated herein by reference.

21
22 This application further relates to disclosure in U.S.
23 Disclosure Document No. 498,720 filed on August 17, 2001 that
24 is entitled in part "Electric Motor Powered Rock Drill Bit
25 Having Inner and Outer Counter-Rotating Cutters and Having
26 Expandable/Retractable Outer Cutters to Drill Boreholes into
27 Geological Formations", an entire copy of which is
28 incorporated herein by reference.

29
30 Still further, this application also relates to
31 disclosure in U.S. Disclosure Document No. 499,136 filed on
32 August 26, 2001, that is entitled in part 'Commercial System
33 Specification PCP-ESP Power Section for Cased Hole Internal
34

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1 Conveyance "Large Well Locomotive™", an entire copy of which
2 is incorporated herein by reference.

3
4 And yet further, this application also relates to
5 disclosure in U.S. Disclosure Document No. 516,982 filed on
6 August 20, 2002, that is entitled "Feedback Control of RPM
7 and Voltage of Surface Supply", an entire copy of which is
8 incorporated herein by reference.
9

10 And finally, this application also relates to disclosure
11 in U.S. Disclosure Document No. 531,687 filed May 18, 2003,
12 that is entitled "Specific Embodiments of Several SDCI
13 Inventions", an entire copy of which is incorporated herein
14 by reference.
15

16 Various references are referred to in the above defined
17 U.S. Disclosure Documents. For the purposes herein, the term
18 "reference cited in applicant's U.S. Disclosure Documents"
19 shall mean those particular references that have been
20 explicitly listed and/or defined in any of applicant's above
21 listed U.S. Disclosure Documents and/or in the attachments
22 filed with those U.S. Disclosure Documents. Applicant
23 explicitly includes herein by reference entire copies of each
24 and every "reference cited in applicant's U.S. Disclosure
25 Documents". To best knowledge of applicant, all copies of
26 U.S. Patents that were ordered from commercial sources that
27 were specified in the U.S. Disclosure Documents are in the
28 possession of applicant at the time of the filing of the
29 application herein.
30

31 Related U.S. Trademarks
32

33 Various references are referred to in the above defined
34 U.S. Disclosure Documents. For the purposes herein, the term

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1 "reference cited in applicant's U.S. Disclosure Documents"
2 shall mean those particular references that have been
3 explicitly listed and/or defined in any of applicant's above
4 listed U.S. Disclosure Documents and/or in the attachments
5 filed with those U.S. Disclosure Documents. Applicant
6 explicitly includes herein by reference entire copies of each
7 and every "reference cited in applicant's U.S. Disclosure
8 Documents". In particular, applicant includes herein by
9 reference entire copies of each and every U.S. Patent cited
10 in U.S. Disclosure Document No. 452648, including all its
11 attachments, that was filed on March 5, 1999. To best
12 knowledge of applicant, all copies of U.S. Patents that were
13 ordered from commercial sources that were specified in the
14 U.S. Disclosure Documents are in the possession of applicant
15 at the time of the filing of the application herein.
16

17 Applications for U.S. Trademarks have been filed in the
18 USPTO for several terms used in this application.
19 An application for the Trademark "Smart Shuttle™" was filed
20 on February 14, 2001 that is Serial No. 76/213676, an entire
21 copy of which is incorporated herein by reference. The
22 "Smart Shuttle™" is also called the "Well Locomotive™". An
23 application for the Trademark "Well Locomotive™" was filed on
24 February 20, 2001 that is Serial Number 76/218211, an entire
25 copy of which is incorporated herein by reference. An
26 application for the Trademark of "Downhole Rig" was filed on
27 June 11, 2001 that is Serial Number 76/274726, an entire copy
28 of which is incorporated herein by reference. An application
29 for the Trademark "Universal Completion Device™" was filed on
30 July 24, 2001 that is Serial Number 76/293175, an entire copy
31 of which is incorporated herein by reference. An application
32 for the Trademark "Downhole BOP" was filed on August 17, 2001
33 that is Serial Number 76/305201, an entire copy of which is
34 incorporated herein by reference.

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Accordingly, in view of the Trademark Applications, the term "smart shuttle" will be capitalized as "Smart Shuttle"; the term "well locomotive" will be capitalized as "Well Locomotive"; the term "downhole rig" will be capitalized as "Downhole Rig"; the term "universal completion device" will be capitalized as "Universal Completion Device"; and the term "downhole bop" will be capitalized as "Downhole BOP".

BACKGROUND OF THE INVENTION

1. Field of Invention

The fundamental field of the invention relates to methods and apparatus that may be used to drill and complete wells at great lateral distances from a drill site. The invention may be used to reach any lateral distance from the surface drill site, from close to the drill site, to a maximum radial distance of at least 20 miles from the surface drill site. This is accomplished by using a near neutrally buoyant umbilical that is attached to a subterranean electric drilling machine. The near neutrally buoyant umbilical is capable of providing up to 320 horsepower to do work at lateral distances of at least 20 miles. This drilling application requires near neutrally buoyant umbilicals capable of providing high power at great distances and high speed data communications to and from the surface. The near neutrally buoyant umbilical reduces the frictional drag of the umbilical within the wellbore. To convey drilling equipment to great distances also requires methods and apparatus to move heavy equipment through pipes at relatively high speeds. Similar high power umbilicals having high speed data communications to and from the surface

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1 are also useful for providing power and communications to
2 remotely operated vehicles used for subsea service work in
3 the oil and gas industry.

4

5 Such high power electrically heated composite umbilicals
6 are also useful as immersion heaters to be installed, or
7 retrofitted, into subsea flowlines to prevent the formation
8 of waxes and hydrates and to prevent the blockage of the
9 flowlines. Such retrofitted electrically heated composite
10 umbilicals provide an alternative for previously installed,
11 but failed, permanent heating systems. A hydraulic pump
12 installed on the distant end of an electrically heated
13 composite umbilical also provides artificial lift to the
14 produced hydrocarbons. Other electrically heated umbilicals
15 used as immersion heaters are also described. Such immersion
16 heater systems may be removed from the well, repaired, and
17 retrofitted into flowlines without removing the flowlines.
18 Near neutrally buoyant electrically heated umbilicals are
19 described which may be installed great distances into
20 flowlines. Different methods of deploying the electrically
21 heated umbilicals are also discussed.

22

23

24 **2. Description of the Related Art**

25

26 The oil and gas industry does not now have the
27 capability to drill horizontally extreme distances of
28 approximately 20 miles to commercially meet some of the
29 challenges that exist today. Industry extended
30 reach-drilling capability is currently between 6 and 7 miles.
31 Conventional drilling rigs using drill pipe and mud motors at
32 shallow angles have established these conventional records.
33 These wells have pushed conventional drilling technologies

34

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1 close to their practical limit and new methods are required
2 for longer offsets.

3

4 The industry's lack of a 20 mile drilling capability
5 reduces accessibility to oil and gas reserves. Many areas,
6 both onshore and offshore, have no surface access for
7 development drilling. Onshore, this may be due to urban
8 development as is the case in Holland, national parks or
9 other special areas such as the Arctic National Wildlife
10 Refuge (ANWR), or other land uses that are sensitive to
11 surface drilling operations. Offshore, the incentive is to
12 maximize the use of existing structures and infrastructure by
13 replacing expensive flowlines, manifold and trees. Near
14 shore regions as found in the Santa Barbara Channel, and
15 especially where ice may be present such as in the Arctic or
16 near Sakhalin Island, or where migrating whales may limit
17 seasonal operations provide significant incentives for this
18 new 20 mile drilling capability.

19

20 The industry does not have an extreme reach lateral
21 drilling system that is compatible with existing drilling and
22 production infrastructure. If such a system were available,
23 new roads, drill sites, pits, site remediation, permitting,
24 etc. are all avoided in such onshore operations. Offshore,
25 existing host structures will have greatly extended
26 usefulness while reservoirs within 20-mile radii may be
27 developed.

28

29 The industry does not have an extreme reach drilling
30 capability that reduces the risk to the environment. If such
31 a system were available, then operating from drilling and
32 production centers would allow using subsurface access to the
33 reservoirs. There would be no surface flowlines or
34 facilities outside the regional drilling and production

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1 center. Extreme reach lateral drilling systems could
2 eliminate the need for many of the flowlines on the ocean
3 bottom in a regional development. However, centralized
4 surface operations with fixed facilities require a paradigm
5 shift in development drilling operations. The well drilling
6 and maintenance equipment would not normally be mobile
7 (except offshore on vessels) and it would normally spend its
8 entire working life from one location.

9

10 Several references are cited below related to the topics
11 of expandable casing, methods to expand tubulars and casings,
12 fabricating composite umbilicals, and well management
13 systems.

14

15 Relevant references to expandable casing includes
16 U.S. Patent No. 5,667,011, entitled "Method of Creating a
17 Casing in a Borehole", which issued on September 16, 1997,
18 that is assigned to Shell Oil Company of Houston, Texas,
19 and the following U.S. Patents, entire copies of which are
20 incorporated herein by reference:

21

22 U.S. 5,366,012; U.S. 5,348,095; U.S. 5,240,074;
23 U.S. 4,716,965; U.S. 4,501,327; U.S. 4,495,997;
24 U.S. 3,958,637; U.S. 3,203,451; U.S. 3,172,618;
25 U.S. 3,052,298; U.S. 2,447,629; U.S. 2,207,478

26

27

28 Relevant references to expandable casing also includes
29 U.S. Patent No. 6,431,282, entitled "Method for Annular
30 Sealing", which issued on August 13, 2002, that is assigned
31 to Shell Oil Company of Houston, Texas, and the following
32 U.S. Patents, entire copies of which are incorporated
33 herein by reference:

34

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1 U.S. 6,012,522; U.S. 5,964,288; U.S. 5,875,845;
2 U.S. 5,833,001; U.S. 5,794,702; U.S. 5,787,984;
3 U.S. 5,718,288; U.S. 5,667,011; U.S. 5,337,823;
4 U.S. 3,782,466; U.S. 3,489,220; U.S. 3,363,301;
5 U.S. 3,297,092; U.S. 3,191,680; U.S. 3,134,442;
6 U.S. 3,126,959; U.S. 2,294,294; U.S. 2,248,028

7

8

9 Other relevant foreign patent documents related
10 expandable casing include the following, entire copies of
11 which are incorporated herein by reference:

12

13 E.P. 0,643,794; W.O. 09,933,763; W.O. 09,923,046;
14 W.O. 09,906,670; W.O. 09,902,818; W.O. 09,703,489;
15 W.O. 09,519,942; W.O. 09,419,574; W.O. 09,409,252;
16 W.O. 09,409,250; W.O. 09,409,249

17

18

19 Other publications related to expandable casing include
20 the following documents related to Enventure Global
21 Technology of Houston, Texas, entire copies of which are
22 incorporated herein by reference:

23

24 (a) Campo, D., et al., "Drilling and Recompletion
25 Applications Using Solid Expandable Tubular Technology",
26 SPE/IADC 72304 at 2002 SPE/IADC Middle East Drilling
27 Technology Conference and Exhibition, 11 March 2002.

28

29 (b) Moore, M., et al., "Field Trial Proves Upgrades to Solid
30 Expandable Tubulars", OTC 14217 at 2002 Offshore Technology
31 Conference, 6-9 May 2002.

32

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34

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- 1 (c) Grant, T., et al., "Deepwater Expandable Openhole Liner
2 Case Histories: Learnings Through Field Applications", OTC
3 14218 at 2002 Offshore Technology Conference, 6-9 May 2002.
4
- 5 (d) Dupal, K., et al., "Realization of the Mono-Diameter
6 Well: Evolution of a Game-Changing Technology", OTC 14312 at
7 2002 Offshore Technology Conference, 6-9 May 2002.
8
- 9 (e) Moore, M., et al., "Expandable Linear Hangers: Case
10 Histories", OTC 14313 at 2002 Offshore Technology Conference,
11 6-9 May 2002.
12
- 13 (f) Nor, N., et al., "Transforming Conventional Wells to
14 Bigbore Completions Using Solid Expandable Tubular
15 Technology", OTC 14315 at 2002 Offshore Technology
16 Conference, 6-9 May 2002.
17
- 18 (g) Merritt, R., et al., "Well Remediation Using Expandable
19 Cased-Hole Liners - Summary of Case Histories", Texas Tech
20 University's Southwestern Petroleum Short Course - 2002
21 Conference.
22
- 23 (h) Cales, G., et al., "Subsidence Remediation - Extending
24 Well Life Through the Use of Solid Expandable Casing
25 Systems", AADE 01-NC-HO-24 at March 2001 Conference.
26
- 27 (i) Dupal, K., et al., "Solid Expandable Tubular
28 Technology - A Year of Case Histories in the Drilling
29 Environment", SPE/IADC 67770 at 2001 SPE/IADC Drilling
30 Conference 27 February - 1 March 2001.
31
- 32 (j) Dupal, K., et al., "Well Design With Expandable Tubulars
33 Reduces Costs and Increases Success in Deepwater
34 Applications", Deep Offshore Technology, 2002.

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1 (k) Daigle, C., et al., "Expandable Tubulars: Field Examples
2 of Application in Well Construction and Remediation", SPE
3 62958 at SPE Annual Technical Conference and Exhibition, 1-4
4 October 2000.

5
6 (l) Bullock, M., et al., "Using Expandable Solid Tubulars to
7 Solve Well Construction Challenges in Deep Waters and
8 Maturing Properties", IPB 275 00 at the Rio Oil & Gas
9 Conference, 16-19 October 2000.

10
11 (m) Mack, A., et al., "In-Situ Expansion of Casing and
12 Tubing - Effect on Mechanical Properties and Resistance to
13 Sulfide Stress Cracking", NACE 00164 at the NACE Expo
14 Corrosion 2000 Conference, 26-30 March 2000.

15
16 (n) Lohoefer, C., et al., "Expandable Liner Hanger Provides
17 Cost-Effective Alternative Solution", IADC/SPE 59151 at 2000
18 IADC/SPE Drilling Conference, 23-25 February 2000.

19
20 (o) Filippov, A., et al., "Expandable Tubular Solutions",
21 SPE 56500 at 1999 SPE Annual Technical Conference and
22 Exhibition, 3-6 October 1999.

23
24 (p) Haut, R., et al., "Meeting Economic Challenge of
25 Deepwater Drilling with Expandable-Tubular Technology", Deep
26 Offshore Technology Conference, 1999.

27
28 (q) Bayfield, M., et al., "Burst and Collapse of a Sealed
29 Multilateral Junction: Numerical Simulations", SPE/IADC 52873
30 at 1999 SPE/IADC Drilling Conference, 9-11 March 1999.

31
32
33 Relevant references related to expandable casing also
34 include U.S. Patent No. 6,354,373, entitled "Expandable

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1 Tubing for a Well Bore Hole and Method of Expanding", which
2 issued on March 12, 2002, that is assigned to the
3 Schlumberger Technology Corporation of Houston, Texas, and
4 the following U.S. Patents, entire copies of which are
5 incorporated herein by reference:

6
7 U.S. 6,012,522; U.S. 5,631,557; U.S. 5,494,106;
8 U.S. 5,366,012; U.S. 5,348,095; U.S. 5,337,823;
9 U.S. 5,200,072; U.S. 5,083,608; U.S. 5,014,779;
10 U.S. 4,976,322; U.S. 5,830,109; U.S. 4,716,965;
11 U.S. 4,501,327; U.S. 4,495,997; U.S. 4,308,736;
12 U.S. 3,948,321; U.S. 3,785,193; U.S. 3,691,624;
13 U.S. 3,489,220; U.S. 3,477,506; U.S. 3,364,993;
14 U.S. 3,353,599; U.S. 3,326,293; U.S. 3,054,455;
15 U.S. 3,028,915; U.S. 2,734,580; U.S. 2,447,629;
16 U.S. 2,214,226; U.S. 1,652,650; U.S. 341,327

17

18

19 Other relevant foreign patent documents related to
20 expandable casing include the following, entire copies of
21 which are incorporated herein by reference:

22

23 S.U. 1,747,673; S.U. 1,051,222; W.O. 93/25799

24

25

26 Relevant references for methods to expand tubulars and
27 casings include U.S. Patent No. 6,325,148, entitled "Tools
28 and Methods for Use with Expandable Tubulars", which issued
29 on December 4, 2001, that is assigned to Weatherford/Lamb,
30 Inc. of Houston, Texas, and the following U.S. Patents,
31 entire copies of which are incorporated herein by reference:

32

33 U.S. 6,070,671; U.S. 6,029,748; U.S. 5,979,571;
34 U.S. 5,960,895; U.S. 5,924,745; U.S. 5,901,789;

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1 U.S. 5,887,668; U.S. 5,785,120; U.S. 5,706,905;
2 U.S. 5,667,011; U.S. 5,636,661; U.S. 5,560,426;
3 U.S. 5,553,679; U.S. 5,520,255; U.S. 5,472,057;
4 U.S. 5,409,059; U.S. 5,366,012; U.S. 5,348,095;
5 U.S. 5,322,127; U.S. 5,307,879; U.S. 5,301,760;
6 U.S. 5,271,472; U.S. 5,267,613; U.S. 5,156,209;
7 U.S. 5,052,849; U.S. 5,052,483; U.S. 5,014,779;
8 U.S. 4,997,320; U.S. 4,976,322; U.S. 4,883,121;
9 U.S. 4,866,966; U.S. 4,848,469; U.S. 4,807,704;
10 U.S. 4,626,129; U.S. 4,581,617; U.S. 4,567,631;
11 U.S. 4,505,612; U.S. 4,505,142; U.S. 4,502,308;
12 U.S. 4,487,630; U.S. 4,483,399; U.S. 4,470,280;
13 U.S. 4,450,612; U.S. 4,445,201; U.S. 4,414,739;
14 U.S. 4,407,150; U.S. 4,387,502; U.S. 4,382,379;
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16 U.S. 4,319,393; U.S. 3,977,076; U.S. 3,948,321;
17 U.S. 3,820,370; U.S. 3,785,193; U.S. 3,780,562;
18 U.S. 3,776,307; U.S. 3,746,091; U.S. 3,712,376;
19 U.S. 3,691,624; U.S. 3,689,113; U.S. 3,669,190;
20 U.S. 3,583,200; U.S. 3,489,220; U.S. 3,477,506;
21 U.S. 3,354,955; U.S. 3,353,599; U.S. 3,326,293;
22 U.S. 3,297,092; U.S. 3,245,471; U.S. 3,203,483;
23 U.S. 3,203,451; U.S. 3,195,646; U.S. 3,191,680;
24 U.S. 3,191,677; U.S. 3,186,485; U.S. 3,179,168;
25 U.S. 3,167,122; U.S. 3,039,530; U.S. 3,028,915;
26 U.S. 2,633,374; U.S. 2,627,891; U.S. 2,519,116;
27 U.S. 2,499,630; U.S. 2,424,878; U.S. 2,383,214;
28 U.S. 2,214,226; U.S. 2,017,451; U.S. 1,981,525;
29 U.S. 1,880,218; U.S. 1,301,285; U.S. 988,504
30
31

32 Other relevant foreign patent documents related to
33 methods to expand tubulars and casings include the following,
34 entire copies of which are incorporated herein by reference:

"HIGH POWER UMBILICALS FOR
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1 W.O. 99/23354; W.O. 99/18328; W.O. 99/02818; W.O. 98/00626;
2 W.O. 97/21901; W.O. 94/25655; W.O. 93/24728; W.O. 92/01139
3 G.B. 2329918A; G.B. 2320734A; G.B. 2313860B; G.B. 2216926A;
4 G.B. 1582392; G.B. 1457843; G.B. 1448304; G.B. 1277461;
5 G.B. 997721; G.B. 792886; G.B. 730338;
6 E.P. 0 961 007 A2; E.P. 0 952 305 A1; E.P. WO93/25800;
7 D.E. 4133802C1; D.E. 3213464A1

8

9

10 Another relevant publication related to methods to
11 expand tubulars and casings includes the following, an entire
12 copy of which is incorporated herein by reference:

13

14 Metcalfe, P. "Expandable Slotted Tubes Offer Well Design
15 Benefits", Petroleum Engineer International, vol. 69, No. 10
16 (Oct 1996), pp 60-63.

17

18

19 Relevant references for fabricating composite umbilicals
20 includes U.S. Patent No. 6,357,485, entitled "Composite
21 Spoolable Tube", which issued on March 19, 2002, that is
22 assigned to the Fiberspar Corporation, and the following
23 U.S. Patents, entire copies of which are incorporated herein
24 by reference:

25

26 U.S. 6,286,558; U.S. 6,148,866; U.S. 5,921,285;
27 U.S. 6,016,845; U.S. 646,887; U.S. 1,930,285;
28 U.S. 2,648,720; U.S. 2,690,769; U.S. 2,725,713;
29 U.S. 2,810,424; U.S. 3,116,760; U.S. 3,277,231;
30 U.S. 3,334,663; U.S. 3,379,220; U.S. 3,477,474;
31 U.S. 3,507,412; U.S. 3,522,413; U.S. 3,554,284;
32 U.S. 3,579,402; U.S. 3,604,461; U.S. 3,606,402;
33 U.S. 3,692,601; U.S. 3,700,519; U.S. 3,701,489;
34 U.S. 3,734,421; U.S. 3,738,637; U.S. 3,740,285;

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1 U.S. 3,769,127; U.S. 3,783,060; U.S. 3,828,112;
2 U.S. 3,856,052; U.S. 3,856,052; U.S. 3,860,742;
3 U.S. 3,933,180; U.S. 3,956,051; U.S. 3,957,410;
4 U.S. 3,960,629; U.S. RE29,122; U.S. 4,053,343;
5 U.S. 4,057,610; U.S. 4,095,865; U.S. 4,108,701;
6 U.S. 4,125,423; U.S. 4,133,972; U.S. 4,137,949;
7 U.S. 4,139,025; U.S. 4,190,088; U.S. 4,200,126;
8 U.S. 4,220,381; U.S. 4,241,763; U.S. 4,248,062;
9 U.S. 4,261,390; U.S. 4,303,457; U.S. 4,308,999;
10 U.S. 4,336,415; U.S. 4,463,779; U.S. 4,515,737;
11 U.S. 4,522,235; U.S. 4,530,379; U.S. 4,556,340;
12 U.S. 4,578,675; U.S. 4,627,472; U.S. 4,657,795;
13 U.S. 4,681,169; U.S. 4,728,224; U.S. 4,789,007;
14 U.S. 4,992,787; U.S. 5,097,870; U.S. 5,170,011;
15 U.S. 5,172,765; U.S. 5,176,180; U.S. 5,184,682;
16 U.S. 5,209,136; U.S. 5,285,008; U.S. 5,285,204;
17 U.S. 5,330,807; U.S. 5,334,801; U.S. 5,348,096;
18 U.S. 5,351,752; U.S. 5,428,706; U.S. 5,435,867;
19 U.S. 5,443,099; U.S. RE35,081; U.S. 5,469,916;
20 U.S. 5,551,484; U.S. 5,730,188; U.S. 5,755,266;
21 U.S. 5,828,003; U.S. 5,921,285; U.S. 5,933,945;
22 U.S. 5,951,812; U.S. 6,016,845; U.S. 6,148,866;
23 U.S. 6,286,558; U.S. 6,004,639; U.S. 6,361,299
24
25

26 Other relevant foreign patent documents related to
27 fabricating composite umbilicals include the following,
28 entire copies of which are incorporated herein
29 by reference:

30
31 DE 4214383; EP 0024512; EP 352148; EP 505815; GB 553,110;
32 GB 2255994; GB 2270099
33
34

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1 Other relevant publications related to fabricating
2 composite umbilicals include the following, entire copies of
3 which are incorporated herein by reference:

4
5 (a) Fowler Hampton et al.; "Advanced Composite Tubing
6 Usable", The American Oil & Gas Reporter, pp. 76-81
7 (Sep. 1997).

8
9 (b) Fowler Hampton et al.; "Development Update and
10 Applications of an Advanced Composite Spoolable Tubing",
11 Offshore Technology Conference held in Houston Texas from
12 4th to 7th of May 1998, pp. 157-162.

13
14 (c) Hahan H. Thomas and Williams G. Jerry; "Compression
15 Failure Mechanisms in Unidirectional Composites", NASA
16 Technical Memorandum pp 1-42 (Aug. 1984).

17
18 (d) Hansen et al.; "Qualification and Verification of
19 Spoolable High Pressure Composite Service Lines for the
20 Asgard Field Development Project", paper presented at the
21 1997 Offshore Technology Conference held in Houston Texas
22 from 5th to 8th of May 1997, pp. 45-54.

23
24 (e) Haug et al.,; "Dynamic Umbilical with Composite Tube
25 (DUCT)", Paper presented at the 1998 Offshore Technology
26 Conference held in Houston Texas from 4th to 7th of May,
27 1998, pp.699-712.

28
29 (f) Lundberg et al.; "Spin-off Technologies from Development
30 of Continuous Composite Tubing Manufacturing Process", Paper
31 presented at the 1998 Offshore Technology Conference held in
32 Houston, Texas from 4th to 7th of May 1998, pp. 149-155.

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- 1 (g) Marker et al.; "Anaconda: Joint Development Project
2 Leads to Digitally Controlled Composite Coiled Tubing
3 Drilling System", Paper presented at the SPEI/COTA, Coiled
4 Tubing Roundtable held in Houston, Texas from 5th to 6th of
5 Apr., 2000, pp. 1-9.
- 6
- 7 (h) Measures R.M.; "Smart Structures with Nerves of Glass",
8 Prog. Aerospace Sc. 26(4):289-351 (1989).
- 9
- 10 (i) Measures et al.; "Fiber Optic Sensors for Smart
11 Structures", Optics and Lasers Engineering 16: 127-152 (1992)
- 12
- 13 (j) Popper Peter; "Braiding", International Encyclopedia of
14 Composites, Published by VGH, Publishers, Inc., 220 English
15 23rd Street, Suite 909, New York, NY 10010.
- 16
- 17 (k) Quigley et al., "Development and Application of a Novel
18 Coiled Tubing String for Concentric Workover Services", Paper
19 presented at the 1997 Offshore Technology Conference held in
20 Houston, Texas from 5th to 8th of May 1997, pp. 189-202.
- 21
- 22 (l) Sas-Jaworsky II and Bell Steve "Innovative Applications
23 Stimulated Coiled Tubing Development", World Oil, 217(6): 61
24 (Jun. 1996).
- 25
- 26 (m) Sas-Jaworsky II and Mark Elliot Teel; "Coiled Tubing
27 1995 Update: Production Applications", World Oil, 216 (6): 97
28 (Ju. 1995).
- 29
- 30 (n) Sas-Jaworsky, A. and J.G. Williams, "Advanced composites
31 enhance coiled tubing capabilities", World Oil, pp. 57-69
32 (Apr. 1994).
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- 34

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- 1 (o) Sas-Jaworsky, A. and J.G. Williams, "Development of a
2 composite coiled tubing for oilfield services", Society of
3 Petroleum Engineers, SPE 26536, pp. 1-11 (1993).
4
- 5 (p) Sas-Jaworsky, A. and J.G. Williams, "Enabling
6 capabilities and potential application of composite coiled
7 tubing", Proceedings of World Oil's 2nd International
8 Conference on Coiled Tubing Technology, pp. 2-9 (1994).
9
- 10 (p) Sas-Jaworsky II Alex; "Developments Position CT for
11 Future Prominence", The American Oil & Gas Reporter, pp. 87-
12 92 (Mar. 1996).
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- 14 (r) Moe Wood T., et al.; "Spoolable, Composite Tubing for
15 Chemical and Water Injection and Hydraulic Valve Operation",
16 Proceedings of the 11th International Conference on Offshore
17 Mechanics and Arctic Engineering-1992, vol. III, Part A-
18 Materials Engineering, pp. 199-207 (1992).
19
- 20 (s) Shuart J.M. et al.; "Compression Behavior of 45°-
21 Dominated Laminates with a Circular Hole of Impact Damage",
22 AIAA Journal 24(1): 115-122 (Jan. 1986).
23
- 24 (t) Silverman A. Seth, "Spoolable Composite Pipe for
25 Offshore Applications", Materials Selection & Design pp. 48-
26 50 (Jan. 1997).
27
- 28 (u) Rispler K. et al.; "Composite Coiled Tubing in Harsh
29 Completion/Workover Environments", paper presented at the SPE
30 Gas Technology Symposium and Exhibition held in Calgary,
31 Alberta, Canada, on Mar. 15-18, 1998, pp. 405-410.
32
- 33 (v) Williams G.J. et al.; "Composite Spoolable Pipe
34 Development, Advancements, and Limitations", Paper presented

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1 at the 2000 Offshore Technology Conference held in Houston
2 Texas from 1st to 4th of May 2000, pp. 1-16.
3
4

5 A relevant reference for well management systems
6 includes U.S. Patent No. 6,257,332, entitled "Well Management
7 System", which issued on July 10, 2001, that is assigned to
8 the Halliburton Energy Services, Inc., an entire copy of
9 which incorporated herein by reference.

10
11 Typical procedures used in the oil and gas industries to
12 drill and complete wells are well documented. For example,
13 such procedures are documented in the entire "Rotary Drilling
14 Series" published by the Petroleum Extension Service of The
15 University of Texas at Austin, Austin, Texas that is
16 incorporated herein by reference in its entirety
17 comprised of the following:

18 Unit I - "The Rig and Its Maintenance" (12 Lessons);
19 Unit II - "Normal Drilling Operations" (5 Lessons);
20 Unit III - Nonroutine Rig Operations (4 Lessons);
21 Unit IV - Man Management and Rig Management (1 Lesson);
22 and Unit V - Offshore Technology (9 Lessons). All of the
23 individual Glossaries of all of the above Lessons in their
24 entirety are also explicitly incorporated herein, and all
25 definitions in those Glossaries shall be considered to
26 be explicitly referenced and/or defined herein.

27
28 Additional procedures used in the oil and gas industries
29 to drill and complete wells are well documented in the series
30 entitled "Lessons in Well Servicing and Workover" published
31 by the Petroleum Extension Service of The University of Texas
32 at Austin, Austin, Texas that is incorporated herein by
33 reference in its entirety comprised of all 12 Lessons. All
34 of the individual Glossaries of all of the above Lessons in

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1 their entirety are also explicitly incorporated herein, and
2 any and all definitions in those Glossaries shall be
3 considered to be explicitly referenced and/or defined herein.

Entire copies of each and every reference explicitly cited above in this section entitled "Description of the Related Art" are incorporated herein by reference.

9 At the time of the filing of the application herein,
10 the applicant is unaware of any additional art that is
11 particularly relevant to the invention other than that cited
12 in the above defined "related" U.S. Patents, the "related"
13 co-pending U.S. Patent Applications, the "related" co-pending
14 PCT Application, and the "related" U.S. Disclosure Documents
15 that are specified in the first paragraphs of this
16 application.

SUMMARY OF THE INVENTION

21 An object of the invention is to provide high power
22 umbilicals for subterranean electric drilling.

24 Another object of the invention is to provide high power
25 umbilicals that allow subterranean electric drilling machines
26 to drill boreholes of up to 20 miles laterally from surface
27 drill sites.

29 Another object of the invention is to provide high power
30 umbilicals that allow the subterranean liner expansion tools
31 to install casings within monobore wells to distances of up
32 to 20 miles laterally from surface drill sites.

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1 Another object of the invention is to provide high power
2 near neutrally buoyant umbilicals for subterranean electric
3 drilling to reduce the frictional drag on the umbilicals.
4

5 Yet another object of the invention is to provide a
6 high power near neutrally buoyant umbilical that possesses
7 high speed data communications and also provides a conduit
8 for drilling mud.
9

10 Another object of the invention is to provide an
11 umbilical that delivers in excess of 60 kilowatts to a
12 downhole electric motor that is a portion of a subterranean
13 electric drilling machine.
14

15 Yet another object of the invention is to provide a
16 novel feedback control of a downhole electric motor that is a
17 part of a subterranean electric drilling machine.
18

19 Yet another object of the invention is to provide high
20 power umbilicals to operate subsea remotely operated
21 vehicles.
22

23 Another object of the invention is to provide an
24 umbilical to operate a subsea remotely operated vehicle that
25 possesses high speed data communications and provides a
26 conduit for fluids.
27

28 Yet another object of the invention is to provide a
29 novel feedback control of a downhole electric motor that
30 comprises a portion of a remotely operated vehicle.
31

32 Another object of the invention is to provide electric
33 flowline immersion heater assemblies that may be retrofitted
34 into existing subsea flowlines.

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1 Yet another object of the invention is to provide
2 electrically heated composite umbilicals that may be
3 retrofitted into existing subsea flowlines.

4

5 Another object of the invention is to provide different
6 types of electrically heated composite umbilicals that may be
7 installed within subsea flowlines.

8

9 Yet another object of the invention is to provide
10 different types of electrically heated umbilicals.

11

12 Another object of the invention is to provide different
13 methods to convey electrically heated composite umbilicals
14 into subsea flowlines.

15

16 Yet another object of the invention is to provide
17 different methods to convey electrically heated umbilicals
18 into subsea flowlines.

19

20 Another object of the invention is to provide
21 electrically heated immersion heater systems to prevent the
22 build up of wax and hydrates to prevent the blockage of
23 subsea flowlines.

24

25 Yet another object of the invention is to provide a
26 hydraulic pump attached to the distant end of an electrically
27 heated composite umbilical installed within a flowline to
28 provide artificial lift to the produced hydrocarbons.

29

30 Another object of the invention is to provide a
31 hydraulic pump attached to the distant end of an electrically
32 heated umbilical installed within a flowline to provide
33 artificial lift to the produced hydrocarbons.

34

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1 Yet another object of the invention is to install an
2 electrically heated composite umbilical within a flowline
3 carrying heavy oils to reduce the viscosity of those heavy
4 oils.

Another object of the invention is to provide electrically heated composite umbilicals that are heated uniformly within a flowline.

10 Yet another object of the invention is to provide
11 electrically heated composite umbilicals that are heated
12 nonuniformly within a flowline.

14 Yet another object of the invention is to provide
15 electrically heated composite umbilicals that are
16 substantially neutrally buoyant within the fluids present
17 within the flowlines.

19 Another object of the invention is to provide
20 electrically heated umbilicals that are substantially
21 neutrally buoyant within the fluids present within the
22 flowlines.

24 And finally, it is yet another object of the invention
25 to provide an electrically heated immersion heater system that
26 may be removed from the well, repaired, and retrofitted in
27 the flowline without removing the flowline.

BRIEF DESCRIPTION OF THE DRAWINGS

32 Figure 1 shows a section view of an umbilical that is
33 substantially neutrally buoyant in drilling mud within the
34 well which provides a conduit for drilling fluids that is

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1 capable of providing 320 horsepower of electrical power at a
2 distance of up to 20 miles.

3

4 Figure 2 shows the uphole and downhole power management
5 system for the composite umbilical shown in Figure 1.

6

7 Figure 3 shows an electrical block diagram representing
8 two conductors from one three phase delta circuit providing
9 up to 160 horsepower of electrical power at a distance of
10 up to 20 miles.

11

12 Figure 4 shows an umbilical carousel in the process of
13 being constructed.

14

15 Figure 5 shows a computerized uphole management system
16 for the umbilical that provides for the closed-loop automatic
17 control of all uphole and downhole functions.

18

19 Figure 6 generally shows the subterranean electric
20 drilling machine that is disposed within a previously
21 installed borehole casing during the process of drilling a
22 new borehole and simultaneously installing a section of
23 expandable casing.

24

25 Figure 7 shows the casing hanger.

26

27 Figure 8 shows detail for a downhole pump motor assembly
28 that is related to the downhole pump motor assembly in
29 Figure 6.

30

31 Figure 9 shows a subterranean electric drilling machine
32 boring a new borehole from an offshore platform.

33

34

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1 Figure 10 shows a section view of the subterranean liner
2 expansion tool positioned within an unexpanded casing that is
3 injecting new cement into the new borehole.

4

5 Figure 11 shows the subterranean liner expansion tool in
6 the process of expanding the expandable casing within the new
7 borehole before the new cement sets up.

8

9 Figure 12 shows the casing hanger after a portion of it
10 has been expanded with the casing hanger setting tool inside
11 the previously installed casing.

12

13 Figure 13 shows a section view of the monobore well, or
14 near-monobore well, after passage of the subterranean liner
15 expansion tool.

16

17 Figure 14 shows relevant parameters related to fluid
18 flow rates through the umbilical.

19

20 Figure 15 shows various parameters related to tripping
21 the subterranean electric drilling machine and the expandable
22 casing into the well.

23

24 Figure 16 shows a subterranean electric drilling machine
25 boring a new borehole under the ocean bottom from an
26 onshore wellsite.

27

28 Figure 17 shows a subterranean electric drilling machine
29 boring a new borehole under the earth from a land based
30 drill site.

31

32 Figure 18 shows an open hole subterranean electric
33 drilling machine that is drilling an open borehole in the
34 earth.

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1 Figure 19 shows screw drive subterranean electric
2 drilling machine that is drilling an open borehole in
3 the earth.

4
5 Figure 20 shows a cross section of another embodiment of
6 an umbilical used for subterranean electric drilling
7 machines, for open hole subterranean electric drilling
8 machines, and for other applications.

9
10 Figure 21 shows yet another neutrally buoyant composite
11 umbilical in 12 lb per gallon mud.

12
13 Figure 22 shows an umbilical providing power in excess
14 of 60 kilowatts and communications to a remotely operated
15 vehicle

16
17 Figure 23 shows a umbilical providing power in excess of
18 60 kilowatts, communications, and fluids to a remotely
19 operated vehicle.

20
21 Figure 24 shows a sectional view of one preferred
22 embodiment of a Smart Shuttle™.

23
24 Figure 25 shows a sectional view of a tractor deployer
25 operated from an umbilical.

26
27 Figure 26 shows various devices that may be attached to
28 the Retrieval Sub of the Smart Shuttle and the tractor
29 conveyor.

30
31 Figure 27 shows a diagrammatic representation of
32 functions that may be performed with the Smart Shuttle and
33 the tractor conveyance system.

34

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1 Figure 28 shows a subsea well providing produced
2 hydrocarbons to a fixed platform through several subsea
3 flowlines.

4
5 Figure 29 shows four subsea wells providing produced
6 hydrocarbons to a Floating Production, Storage, and
7 Offloading structure (FPSO) through four different subsea
8 flowlines.

9
10 Figure 30 shows an Electrically Heated Composite
11 Umbilical ("EHCU") installed within a subsea flowline that is
12 providing produced hydrocarbons to a floating platform that
13 was conveyed into place using a particular method of
14 conveyance.

15
16 Figure 31 shows an embodiment of an Electric Flowline
17 Immersion Heater Assembly ("EFIHA") having an Electrically
18 Heated Composite Umbilical ("EHCU") in a subsea flowline that
19 was conveyed into place using a Smart Shuttle that obtains
20 its power from a wireline located within the EHCU.

21
22 Figure 32 shows another embodiment of an Electric
23 Flowline Immersion Heater Assembly ("EHCU") having an
24 Electrically Heated Composite Umbilical in a subsea flowline
25 that was conveyed into place using a Smart Shuttle that
26 obtains its electrical power from additional electrical
27 conductors within the EHCU.

28
29 Figure 33 shows yet another embodiment of an Electric
30 Flowline Immersion Heater Assembly ("EFIHA") having an
31 Electrically Heated Composite Umbilical in a subsea flowline
32 that was conveyed into place using particular methods of
33 operation so that no fluid will be forced into the reservoir
34 during transit of the EFIHA into the flowline.

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1 Figure 34 shows still another embodiment of an Electric
2 Flowline Immersion Heater Assembly having an Electrically
3 Heated Composite Umbilical in a subsea flowline that was
4 conveyed into place using yet another method of conveyance.
5

6 Figure 35 shows an Electrically Heated Composite
7 Umbilical being installed within a flowline by a tractor
8 means, where the host of the flowline is a floating platform.
9

10 Figure 36 shows a Pump-Down Conveyed Flowline Immersion
11 Heater Assembly ("PDCFIHA") possessing an Electrically Heated
12 Composite Umbilical ("EHCU") installed within a flowline,
13 where the host of the flowline is a Floating Production,
14 Storage and Offloading ("FPSO") ship.
15

16 Figure 37 shows a Pump-Down Conveyed Flowline Immersion
17 Heater Assembly ("PDCFIHA") installed within a flowline,
18 where the host of the flowline is a floating platform.
19

20 Figure 37A shows a Pump-Down Conveyed Flowline Immersion
21 Heater Assembly ("PDCFIHA") installed within a flowline to be
22 used for artificial lift during hydrocarbon production, where
23 the host of the flowline is a floating platform.
24

25 Figure 38 shows an Electric Flowline Immersion Heater
26 Assembly ("EFIHA") which possesses an Electrical Heated
27 Composite Umbilical that is used to produce heavy oil from
28 an open borehole that also uses a hydraulic pump for
29 artificial lift.
30

31 Figure 39 an exploratory well with large volume fluid
32 sampling capability obtained from a downhole sampling unit.
33
34

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1 Figure 40 shows an apparatus that provides electrical
2 power from a flowline penetrating connector to other subsea
3 systems.

4
5 Figure 41 shows one embodiment of a composite umbilical
6 used to uniformly heat a flowline.

7
8 Figure 42 shows a first resistor network used to
9 electrically heat a composite umbilical.

10
11 Figure 43 shows an embodiment of a composite umbilical
12 used to nonuniformly heat a flowline.

13
14 Figure 44 shows an embodiment of a second resistor
15 network used to nonuniformly heat a composite umbilical.

16
17 Figure 45 shows an embodiment of an electrically heated
18 umbilical that is surrounded with steel or synthetic armor.

19
20 Figure 46 shows an embodiment of an electrically heated
21 umbilical that possesses an electric cable as a heating
22 element within a steel coiled tubing.

23
24 Figure 47 shows another embodiment of an electrically
25 heated umbilical that possesses an electric cable as a
26 heating element within steel coiled tubing that is surrounded
27 by thermal insulation.

28
29 Figure 48 shows yet another embodiment of an
30 electrically heated umbilical that is a bundled umbilical
31 possessing electric cables and tubes capable of carrying
32 fluids.

33
34

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1 **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

2

3 **Figure 1** shows a section view of a preferred embodiment
4 of an umbilical 2. In this preferred embodiment, substantial
5 portions of the umbilical are fabricated from one or more
6 composite materials. Consequently umbilical 2 is also called
7 a composite umbilical. Composite umbilical 2 provides a
8 connection between the surface and other downhole tools
9 (such as a subterranean electric drilling machine to be
10 described later) which is capable of performing useful work
11 at great distances from a well site. In the preferred
12 embodiment shown in Figure 1, the umbilical is capable of
13 performing useful work at the distance of 20 miles away from
14 a surface drilling site. This statement means that the
15 umbilical is capable of performing useful work at any
16 distance between 0 miles to 20 miles away from a wellsite.
17 This connection is called an umbilical and it does not rotate
18 like drill pipe and its capabilities are different from those
19 of coiled tubing used in drilling operations.

20

21 In particular, Figure 1 shows an umbilical that is
22 substantially neutrally buoyant in any specific density of
23 drilling mud 4 that is present in a wellbore. The drilling
24 mud 4 may also be called the drilling fluid. The symbol for
25 the density of drilling mud is ρ (drilling mud). In this
26 particular example of a preferred embodiment, the density of
27 drilling mud present in the wellbore is 12 lbs/gallon.

28

29 In Figure 1, the composite umbilical is partially
30 fabricated from inside pipe 6. In Figure 1, the umbilical
31 has an inside diameter of ID1. In this particular
32 embodiment, the inside diameter ID1 is equal to 4.5 inches.
33 The inside diameter forms a hollow region through which
34 fluids may be sent to, and from downhole. Put another way,

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1 the inside diameter forms a conduit through which fluids may
2 be sent from the surface downhole, or from downhole to the
3 surface. Therefore, the umbilical possesses a fluid conduit
4 for conducting drilling fluids through the interior of the
5 umbilical. The fluids present within the inside pipe are
6 shown by element 8 in Figure 1. The density of the
7 fluids 8 is defined to be the symbol ρ (umbilical fluid).
8 For example, drilling mud may be sent downhole through the
9 4.5 inch ID pipe. The ID of this pipe is also called the
10 interior of this pipe. The inside pipe 6 has wall thickness
11 T1, but this legend is not shown in Figure 1 for brevity.
12 In this preferred embodiment, the wall thickness of the
13 inside pipe T1 is 0.25 inches. The wall of the inside
14 pipe 6 is made from a composite material. This composite
15 wall may have many layers of different composite materials
16 made of different materials, each layer having a different
17 specific gravity. As an example of one preferred embodiment,
18 the composite material may be a carbon-based composite
19 material. For reasons of simplicity, those layers are not
20 shown in Figure 1. However, there will be an average
21 specific gravity of the interior pipe that is defined to be
22 SG(inside pipe). In this preferred embodiment, the specific
23 gravity of the inside pipe is equal to 1.5.

24

25 In Figure 1, the composite umbilical is partially
26 fabricated from outside pipe 10. In Figure 1, the umbilical
27 has an outside diameter of OD2 and this legend is shown in
28 Figure 1. In this preferred embodiment, the outside diameter
29 OD2 is equal to 6.00 inches O.D. Consequently, the external
30 portion of the composite umbilical appears to be a pipe
31 having the outside diameter of OD2. The outside pipe 10 has
32 wall thickness T2, but this legend is not shown in
33 Figure 1 for brevity. In this preferred embodiment, the wall
34 thickness of the outside pipe T2 is 0.25 inches. The wall

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1 of the outside pipe 10 is made from a composite material.
2 This composite wall may have many layers of different
3 composite materials made of different materials, each layer
4 having a different specific gravity. In one preferred
5 embodiment, the composite material may be a carbon-based
6 composite material. Those layers are not shown in Figure 1
7 for simplicity. For example, an outer layer of composite
8 material may be chosen to be particularly abrasion resistant.
9 As one example, the outer layer of composite material may be
10 made of a carbon-based composite material. However, there
11 will be an average specific gravity of the outside pipe that
12 is defined to be SG(outside pipe). In this preferred
13 embodiment, the specific gravity of the outside pipe is equal
14 to 1.5.

15

16 As shown in Figure 1, the interior pipe 6 is
17 asymmetrical located within the exterior pipe 10 that forms
18 an the asymmetric volume 12 between the two pipes. Within
19 the asymmetric volume 12 between the two pipes are insulated
20 current carrying electric wires designated by the legends A,
21 B, C, D, E, and F in Figure 1. Also shown in Figure 1 is
22 high speed data link 14. This high speed data link provides
23 high speed data communications from the surface to downhole
24 equipment, and from the downhole equipment to the surface.
25 High speed data link 14 is selected from a list including a
26 fiber optic cable, a coaxial cable, and twisted wire cables.
27 In the particular preferred embodiment of the invention shown
28 in Figure 1, the high speed data link is chosen to be a fiber
29 optic cable. The asymmetric volume 12 between the two pipes
30 that contains wires A, B, C, D, E, and F, and the fiber optic
31 cable, is otherwise filled with syntactic foam material.
32 This syntactic foam material is often made from silica
33 microspheres that are embedded in a filler material, such as
34 epoxy resin or other composite materials. The syntactic foam

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1 material has a specific gravity that is defined as
2 SG(syntactic foam material). In this preferred embodiment of
3 the invention, the specific gravity of the syntactic foam
4 material is 0.825. In this preferred embodiment of the
5 invention, syntactic foam material possessing silica
6 microspheres is provided by the Cumming Corporation. The
7 Cumming Corporation is located at 225 Bodwell Street, Avon,
8 MA 02322. The Cumming Corporation can also be reached by
9 telephone at (508) 580-2660 or by the internet at
10 www.emersoncumming.com. The details on the syntactic foam
11 material may be reviewed in detail in Attachment 28 to
12 Provisional Patent Application Number 60/384,964, that has
13 the Filing Date of June 3, 2002, an entire copy of which is
14 incorporated herein by reference. Using silica microspheres
15 in a syntactic matrix provides the necessary buoyancy in high
16 pressure wellbores. The high axial strength of the composite
17 pipe construction compensates for variations in axial loads
18 caused by mud weight and other density variations.
19

20 In Figure 1, wires A, B, C, D, E, and F are 0.355 inches
21 O.D. insulated No. 4 AWG Wire. The insulation is rated at
22 14,000 volts DC, or 0-peak AC. Wires A, B, and C comprise
23 the first independent three phase delta circuit. Wires D, E,
24 and F comprise the second independent three phase delta
25 circuit. Each separate circuit is capable of providing 160
26 horsepower (119 kilowatts) over an umbilical length of 20
27 miles at the temperature of 150 degrees C. So, combined,
28 the umbilical can deliver a total of 320 horsepower
29 (238 kilowatts) at 20 miles to do work at that distance.
30 At 320 horsepower, less than 1 watt per foot of power is
31 dissipated in the form of heat, which makes this a practical
32 design even if the umbilical is completely wound up on an
33 umbilical carousel as shown in a later figure (Figure 4). In
34 this preferred embodiment, wires A, B, C, D, E, and F are

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1 No. 4 AWG stranded silver plated copper wire which are
2 covered with insulation rated to 14,000 VDC at 200 degrees C,
3 where each wire has a DC resistance of 0.250 ohms per 1000
4 feet at the temperature of 20 degrees C, where the nominal
5 outside diameter of each insulated wire is 0.355 inches, and
6 where each wire weighs 180 lbs/1000 feet. Each wire is Part
7 Number FEP4FLEXSC provided by Allied Wire & Cable, Inc. which
8 is located at 401 East 4th Street, Bridgeport, PA 19405,
9 which may be reached by telephone at (800) 828-9473. The
10 details on Allied Part Number FEP4FLEXSC may be reviewed in
11 Attachment 27 to Provisional Patent Application Number
12 60/384,964, that has the Filing Date of June 3, 2002, an
13 entire copy of which is incorporated herein by reference.

14

15 If the inside pipe 6 is carrying 12 lb per gallon mud,
16 and if the exterior pipe is immersed in 12 lb per gallon mud
17 in the well, then the upward buoyant force in the above
18 preferred embodiment of the umbilical is plus 5.9 lbs per
19 1000 feet of this umbilical. Assuming a coefficient of
20 friction of 0.2, the total frictional "pull-back" on 20 miles
21 of this umbilical is only 124 lbs. This "pull-back" does not
22 include any differential fluid drag forces. This umbilical
23 was chosen to have an extreme length which shows that the
24 essentially neutrally buoyant umbilical overcomes most
25 friction problems associated with umbilicals disposed in
26 wells. For the details of this calculation of a net upward
27 force of 5.9 lbs as described above, please refer to "Case J"
28 of Attachment 34 to Provisional Patent Application Number
29 60/384,964, that has the Filing Date of June 3, 2002, an
30 entire copy of which is incorporated herein by reference.
31 Those particular calculations were performed on the date of
32 November 12, 2001. In these calculations, the density of
33 water of 62.43 lbs/cubic foot was used to calculate the net
34 forces acting on volumes having particular specific

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1 gravities. Please also see other relevant buoyancy
2 calculations in Attachments 29 to 35 of Provisional Patent
3 Application Number 60/384,964.

4
5 The phrase "substantially neutrally buoyant",
6 "essentially neutrally buoyant", "near neutral buoyant", and
7 "approximately neutrally buoyant" may be used
8 interchangeably. For a substantially neutrally buoyant
9 umbilical, or near neutrally buoyant umbilical, the downward
10 force of gravity on a section of the umbilical of a given
11 length is approximately balanced out by the upward buoyant
12 force of well fluid acting on the umbilical of that given
13 length. The density of mud in the well is strongly
14 influenced by any cuttings from any drilling machine attached
15 to the umbilical (to be described later). Similarly, the
16 density of the fluids inside pipe 6 may also be strongly
17 influenced by any cuttings from the drilling machine
18 (if reverse flow is used). So, the density of the drilling
19 mud 4 and the density of fluids present within the pipe 8 may
20 vary with distance along the length of the umbilical.
21 However, at any position along the length of the umbilical
22 which is disposed in the well, the umbilical may be designed
23 to be "substantially neutrally buoyant", "essentially
24 neutrally buoyant", "near neutral buoyant" or "approximately
25 neutrally buoyant". In addition, using the design principles
26 described herein, the entire length of the umbilical may be
27 designed to be on average "substantially neutrally buoyant",
28 "essentially neutrally buoyant", "near neutral buoyant", or
29 "approximately neutrally buoyant" over the entire length of
30 the umbilical that is disposed within a wellbore.
31

32 An umbilical that is "substantially neutrally buoyant",
33 "essentially neutrally buoyant", "near neutral buoyant", or
34 "approximately neutrally buoyant" greatly reduces the

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frictional drag on the umbilical as it moves in the wellbore.
That statement is evident from the following. The net
force on a length of umbilical from gravity and buoyant
forces is F . The coefficient of sliding friction is k .
Therefore, the net "pull back force" P for the given length
of the umbilical is given by:

$$P = F \cdot k$$

Equation 1.

The requirement of a near neutrally buoyant umbilical greatly reduces the frictional drag on the umbilical as it moves in the wellbore. This is a particularly important point. If an umbilical is "substantially neutrally buoyant", "essentially neutrally buoyant", "near neutral buoyant", or "approximately neutrally buoyant" then the frictional drag on the umbilical is greatly reduced as it moves through the wellbore. There are other details to consider such as the starting friction, any sticky substances in the well, drag due to viscous forces, etc. However, Equation 1 forms the basis for providing high electrical power through umbilicals at great distances such as 20 miles from a drilling site. As stated before in relation to this preferred embodiment, with a net force on 1,000 feet of the umbilical being only plus 5.9 lbs (an upward force), assuming a coefficient of friction of 0.2, the total frictional "pull-back" on 20 miles of this umbilical is only 124 lbs.

The preferred embodiment also calls for other reasonable design requirements on the umbilical. The umbilical needs significant axial strength (to pull the drilling machine from the well in the event of equipment failure downhole as explained later) that would require a 160,000 lbs design load. The umbilical must provide an internal pressure capacity (shut-in pressure capacity of the well) of about

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1 10,000 psi. The collapse resistance of the umbilical must
2 exceed a 6,000 psi differential pressure. The umbilical must
3 have the ability to work in at least 120 degrees C, and
4 preferably, 150 degrees C. Composites are now routinely used
5 at 120 degrees C, and experiments are now being conducted on
6 composites at 150 degrees C. Hollow high-strength glass may
7 replace carbon fiber composites for a cost savings, but there
8 will be a weight penalty, thereby increasing frictional drag.
9

10 The umbilical may occasionally be damaged during its use
11 and require field repairs. Repairs will be accomplished by
12 cutting out the damaged part and using field installable end
13 connections to rejoin the intact umbilical sections. The end
14 connections will also join various sections of umbilical that
15 may be stored separately at the surface. These couplings are
16 expected to slightly reduce the ID and increase the
17 umbilical OD.

18 The particular asymmetric design shown in Figure 1 was
19 selected as a preferred embodiment in part because it
20 illustrates the various considerations necessary to design
21 and build such a high power umbilical that is neutrally
22 buoyant in well fluids. Other more symmetric designs for
23 such an umbilical are shown in another preferred embodiment
24 shown in Figure 20 below. The references cited above in the
25 section entitled "Description of the Related Art" provide the
26 generally known methods used in the industry to construct
27 composite umbilicals.

28 **Figure 2** shows the uphole and downhole power management
29 system for the composite umbilical shown in Figure 1. Wires
30 A, B, and fiber optic cable 14, which were identified in
31 Figure 1, are shown in Figure 2. In Figure 2, the surface of
32 the earth is shown figurative as element 16. Any function

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1 shown above element 16 is identified as an "uphole function",
2 and any function shown below element 16 is identified as a
3 "downhole function".

4

5 In Figure 2, only wires A and B of a first three phase
6 delta circuit are shown. Three phase delta is an AC circuit
7 having three wires (for example A, B, and C), each wire of
8 which carries a an AC current, and there exists a voltage
9 difference between each wire. There exists phase
10 relationships between the current vs. time in each wire.
11 There exits phase relationships between the voltage vs. time
12 in each wire. However, in Figure 2, wire C is not shown for
13 simplicity. Electrical generator 18 provides three phase
14 delta power through cable 19 to variable voltage and
15 frequency converter 20. The variable voltage and frequency
16 converter possesses electronics that provides measurement of
17 the voltages, currents and phases of the three phase delta
18 circuit (although that electronics is not shown in Figure 2
19 for the purposes of simplicity). Electrical power is
20 delivered by wires A and B to the downhole electrical
21 load 22. In one preferred embodiment, the electrical load is
22 a downhole electric motor. The voltage, current, the
23 relevant phases, and other parameters of the electrical load
24 are measured with sensing unit 24. Sensing unit 24 is marked
25 with the legend "V" indicating that at least the voltage V is
26 measured between wires A and B at electrical load 22.
27 Sensing unit 24 is attached to the electrical input terminals
28 of the downhole electrical load. If this is a downhole
29 electrical motor, the sensing unit 24 is attached to the
30 electrical input terminals of the electric motor.

31

32 Sensing unit 24 also possesses suitable electronics that
33 sends the measured downhole information to the surface
34 through optical fiber 14. The downhole information is sent

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1 by optical fiber 14 that provides the measured information to
2 computer system 26. The measured downhole information is
3 digitized with related instrumentation (not shown for the
4 purposes of simplicity in Figure 2), and the downhole
5 information is forwarded uphole by light pulses sent through
6 the optical fiber 14.

7
8 In Figure 2, the computer system 26 also possesses
9 related electronics to implement the following. The computer
10 system and related electronics provides commands to the
11 variable voltage and frequency converter 20 by electronic
12 feedback loop 28 to provide the necessary voltage, current,
13 phases, and frequency as required by the downhole load 22.
14 Consequently, Figure 2 shows a closed-loop, dynamic feedback
15 system, where downhole load parameters are measured, the
16 information is sent uphole, and the uphole system is
17 automatically adjusted to provide what is required to
18 properly operate the electrical load. The point is that the
19 feedback loop 28 from computer 20 is used to produce the
20 required frequency, voltage, current and phases required by
21 the downhole load 22. This is an example of the feedback
22 control of the downhole load 22, which may be a downhole
23 electric motor in several preferred embodiments.

24
25 In an alternative embodiment of feedback control, the
26 feedback loop from computer 26 in Figure 2 is used to control
27 the RPM of a motor generator whose 0-peak output voltage may
28 be easily varied, which provides conveniently controlled
29 frequency and voltage outputs, although that minor variation
30 of the preferred embodiment is not shown in a separate figure
31 for the purposes of brevity. In this case, the feedback loop
32 from computer 26 is first used to control the RPM of the
33 motor, and is also used for the second purpose to control the
34 output voltage, frequency, and phase from the generator

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1 attached to the motor which makes the motor generator
2 assembly.

3

4 Additional measured downhole load parameters are also
5 sent uphole through the optical fiber. For example, in one
6 preferred embodiment, element 22 in Figure 2 is an electrical
7 motor, and as an example, the measured RPM, the current drawn
8 by the motor through its input terminals, the voltage across
9 its input terminals, and the phases of the voltages and
10 current vs. time, the temperature, torque, etc. of that
11 electrical motor can be sent uphole through the optical
12 fiber 14. In other preferred embodiments, the electrical
13 load 22 is a submersible electric drilling machine, and in
14 another embodiment, the electrical load is a remotely
15 operated vehicle.

16

17 The system shown in Figure 2 controls a first three
18 phase delta circuit that energizes wires A, B, and C in
19 Figure 1. A second similar system to that shown in
20 Figure 2 controls the power derived to wires D, E and F from
21 a second three phase delta circuit. For simplicity, the
22 second three phase delta circuit is not shown in
23 Figure 2. Such a system is capable of delivering 320
24 horsepower through an umbilical disposed in a wellbore shown
25 in Figure 1 that has a length of up to 20 miles. This is
26 important, because most of the available motors for downhole
27 use are AC motors, and are not DC motors.

28

29 The AC power management system shown in Figure 2 has at
30 least several advantages. First, DC voltages are not used
31 which would generally require a "chopper" to convert DC to AC
32 to operate most currently available downhole electric motors.
33 Such high power choppers are complex, often large, and
34 generate considerable heat. Second, no downhole transformer

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1 is necessary because of the active closed-loop feedback
2 system shown in Figure 2.
3

4 However, the basic feedback control of downhole
5 parameters as such as voltage and current are also useful
6 for a DC power management system for DC electric motors that
7 can be used in a subterranean electric drilling machine.
8 Accordingly, another preferred embodiment of the invention is
9 controlling DC voltages with an analogous system as outlined
10 in Figure 2.

11
12 Figure 3 shows how three phase power of 160 horsepower
13 (119 kilowatts) can be delivered through the electrical
14 conductors in Figures 1 and 2 to distances of 20 miles.
15 This means that this power can be delivered from 0 miles to
16 20 miles away from a drill site for example. Two "legs" of
17 the three phase delta circuit are shown in Figure 3 as wires
18 A and B (wire C of the three phase delta circuit is not shown
19 for simplicity). The resistances of a length of 20 miles of
20 the wire is simulated with resistors having the magnitude of
21 resistance in ohms of "R1". The legend "R1" appears in
22 Figure 3. These two resistors are also respectively labeled
23 as elements 30 and 32. In a preferred embodiment, the load
24 at the end of the umbilical is simulated with a downhole
25 electric motor 34 requiring 2,500 volts 0-peak at 45 amps
26 0-peak between any two wires of the three phase wiring system
27 operating at 60 Hz. As a practical case, this "downhole
28 motor" could in principle be comprised of two each REDA,
29 4 Pole Motors, each requiring 1250 volts 0-peak, at 45 amps
30 0-peak, having a nominal RPM of about 1700 RPM. The current
31 flowing through wires A and B is represented by the legend
32 I(t) in Figure 3. This required motor voltage is represented
33 by the legend $V_M(t)$. The closed-loop, dynamic feedback
34 system described in Figure 2 automatically and continuously

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1 adjusts the voltage provided downhole to the motor that is
2 measured with sensing unit 24 in Figure 2. In this preferred
3 embodiment, typically, the variable voltage and frequency
4 converter 20 in Figure 2 provides 6,182 volts 0-peak and
5 provides 45 amps 0-peak between any two legs of the three
6 phase circuit. The supplied voltage is represented by
7 element 36 in Figure 3. The voltage supplied by the voltage
8 and frequency converter 20 is represented by the legend $V_S(t)$
9 in Figure 3. The point of this is that using the above
10 described feedback system and reasonable gauge wiring, it is
11 possible to actually deliver 160 horsepower (119 kilowatts)
12 at a distance of 20 miles.

13

14 Figure 3 shows a first independent circuit that provides
15 2,500 volts 0-peak to a load, a motor in this preferred
16 embodiment, at distances of up to 20 miles between wires A,
17 B, and C respectively, and the motor may draw up to 45 amps
18 0-peak between any pairs of wires, A-B, B-C, or C-A. A
19 second independent circuit, that is not shown for simplicity,
20 also provides 2,500 volts 0-peak to another motor at
21 distances to 20 miles between wires D, E, and F respectively,
22 and that motor may also draw up to 45 amps 0-peak from any
23 wire D, E, and F. Such voltages and currents are necessary
24 for two series operated REDA 4 Pole Motors, each rated for 80
25 Horsepower (as shown in a later figure, Figure 8). REDA is a
26 manufacturer called "Reda Div. Camco International, Inc."
27 that may be reached at 4th & Dewey, Bartlesville, Oklahoma
28 74005, having the telephone number of (918) 661-2000,
29 that has a website that may be reached through
30 www.schlumberger.com.

31

32 In summary, the umbilical 2 in Figure 1 must carry high
33 power and high speed communications (320 hp - two circuits of
34 160 hp each - and fiber optic communications). An A.C.

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1 voltage, transformerless, downhole electrical power
2 arrangement is used. The input power and voltage are managed
3 topside to maintain constant downhole load voltage. In one
4 preferred embodiment, one of the two circuits is dedicated to
5 the downhole mud pump (or Smart Shuttle™) service, while the
6 second circuit operates other Downhole Rig™ functions such as
7 the rotation and weight loading of a drilling bit, which will
8 be described in later figures. In various preferred
9 embodiments, the various downhole motors feature soft start
10 controls allowing the topside power supply to reliably track
11 power demand.

12

13 In the above preferred embodiment, a three phase delta
14 power circuit is used. In principle, any electrical power
15 system may be used including 208 Y and related power systems,
16 and ordinary single phase power systems.

17

18 **Figure 4** shows an umbilical carousel in the process of
19 being constructed. This equipment is similar to flexible
20 pipe handling equipment now used in the industry. A first
21 carousel flange 38 possesses interior spokes 40 that forms
22 the inside diameter of the umbilical carousel. Wound on
23 those interior spokes is the umbilical 42. A second carousel
24 flange (not shown) encloses the wound up umbilical, although
25 it not shown in the interest of brevity. In one preferred
26 embodiment, the umbilical 42 is the same umbilical as shown
27 in Figure 1 that is 6 inches OD. The umbilical may be stored
28 and operated as a single line. However, the umbilical is
29 preferably divided into several smaller lengths, as an
30 example 5 miles each, and stored on smaller carousals or
31 drums to reduce the fluid friction losses as compared to one
32 20-mile continuous length. A level wind is provided on each
33 carousel to correctly wrap the pipe as it is pulled from the
34 well and returned to the carousel for storage.

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1 Each carousel holding 5 miles of the 6 inch OD umbilical
2 is approximately 8 ft tall with an outside diameter of 22 ft.
3 The mud filled umbilical weighs approximately 234 tons.
4 Unless this equipment is installed on offshore vessels, it is
5 not easily moved. For this reason, drilling centers where
6 the rig is assembled are expected to use the equipment over
7 its useful life. Such carousals may be supplied by Coflexip
8 Stena Offshore, Inc. located at 7660 Woodway, Suite 390,
9 Houston, Texas 77063, having the telephone number
10 (713) 789-8540, which has its website at www.coflexip.com.
11 Such carousals may also be supplied by Oceaneering
12 International, Inc. located at 11911 FM 529, Houston,
13 Texas 77401, having telephone number (713) 329-4500, which
14 has its website at www.oceaneering.com.

15

16 Much surface equipment is needed in support of handling
17 the umbilical. This surface equipment is briefly described
18 in the following. Much of this equipment may be supplied by
19 a firm located in Holland called Huisman-Itrec, that may be
20 located at Admiraal Trompstraat 2 - 3115 HH Schiedam, P.O.
21 Box 150 - 3100 AD Schiedam, The Netherlands, Harbour No. 561,
22 having the telephone number of 31(0) 10 245 22 22, that has
23 its website at www.Huisman-Itrec.com.

24

25 Stripper heads and surface blow-out preventers (BOP's)
26 provide an OD pressure seal to the umbilical, although no
27 figures are provided to show this feature for simplicity.
28 This equipment has a similar function to a coiled tubing
29 stripper head, except it handles the larger umbilical OD
30 sizes. In practice, the actual sealing element is expected
31 to be dual 13 5/8" annular stripping BOPs with grease
32 injection to lubricate the sealing elements as the umbilical
33 moves through the sealing elements. This approach of dual
34 stripping units allows the umbilical mechanical couplings to

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1 be transitioned into the well. The surface BOPs provide for
2 surface well control in the event of a well kick. These
3 (shear, pipe & blind ram) BOPs will be located between the
4 wellhead and the stripping annular units.

5

6 An injector unit is required on the surface, although no
7 figure is shown for simplicity. A 100-ton linear traction
8 unit is preferred for this application. The injection unit
9 provides drilling umbilical pushing and pulling loads at
10 speeds to 10 feet per second. The maximum loads will be at
11 low speeds. Speed will be limited by mudflows within the
12 wellbore. This injector unit has a function similar to a
13 coiled tubing injector but practically is closer in size and
14 performance to a pipeline tensioner used to lay flexible
15 pipe. Similar units are used for the handling and
16 installation of flexible pipe by such firms as Coflexip Stena
17 Offshore, Inc.; Wellstream, Inc.; and NKT Flexibles I/S. The
18 address of Coflexip Stena Offshore, Inc. has been provided
19 above. Wellstream, Inc. is a subsidiary of Halliburton
20 Energy Services, and may be reached at 10200 Bellaire
21 Boulevard, Houston, Texas 77072-5299, having the telephone
22 number of (281) 575-4033. NKT Flexibles I/S is a firm
23 located in Denmark having the address of Priorparken 510,
24 DK-2605 Broendby, Denmark, having the telephone
25 of 45 43 48 30 00, that has its website at
26 www.nktflexibles.com.

27

28 A surface mud system is required for the umbilical,
29 although no figures showing this feature are provided for the
30 sake of brevity. A large volume of working mud will be
31 needed to manage the umbilical volume while tripping in the
32 hole. For 20-mile offset operations, an active mud tank
33 volume of 3,500 barrels may be required. This is similar to
34 some large offshore drilling rigs in capacity. A minimum of

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1 two 750 hp surface mud pumps will be required for the
2 preferred embodiment. The other details concerning the mud
3 system will be presented in relation to a forthcoming figure
4 (Figure 14).

5

6 A surface rig is needed to support umbilical and casing
7 operations, although no figure is presented showing this
8 detail in the interests of brevity. The surface rig handles
9 and makes-up the casing as it is run into the hole. In many
10 respects, it is similar to conventional coiled tubing
11 drilling rigs, except it is much larger in size. During
12 drilling operations, the best method for joining expandable
13 casing is continuing to develop. Enventure Global Technology
14 is developing an expandable threaded joint. Enventure also
15 has commercially available various sizes of expandable pipes
16 and can supply various means of joining lengths of the
17 expandable pipe. Enventure Global Technology may be reached
18 at 16200-A Park Row, Houston, Texas 77084, having the
19 telephone number of (281) 492-5000, that has its website at
20 www.EnventureGT.com. Other alternatives of joining
21 expandable is to weld long casing strings (similar to J-
22 laying pipelines). The arrangement of surface rig equipment
23 is compatible with both alternatives.

24

25 **Figure 5** shows a computerized uphole management system
26 for the umbilical. It is a portion of a preferred embodiment
27 of an automated system to drill and complete
28 oil and gas wells. It is also a portion of a preferred
29 embodiment of a closed-loop system to drill and complete oil
30 and gas wells. Figure 5 shows the computer control of the
31 umbilical carousel in a preferred embodiment of the
32 invention.

33

34

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1 In Figure 5, computer system 26 (previously described in
2 Figure 2) has typical components in the industry including
3 one or more processors, one or more non-volatile memories,
4 one or more volatile memories, many software programs that
5 can run concurrently or alternatively as the situation
6 requires, etc., and all other features as necessary to
7 provide computer control of all of the uphole functions. In
8 this preferred embodiment, this same computer system 26 also
9 has the capability to acquire data from, send commands to,
10 and otherwise properly operate and control all downhole
11 functions. Therefore LWD and MWD data is acquired by this
12 same computer system when appropriate. As a consequence, in
13 one preferred embodiment, the computer system 26 has all
14 necessary components to interact with a subterranean electric
15 drilling machine. In a "closed-loop" operation of the
16 system, information obtained downhole from the downhole
17 system is sent to the computer system that is executing a
18 series of programmed steps, whereby those steps may be
19 changed or altered depending upon the information received
20 from the downhole sensor located within the downhole system.
21

22 In Figure 5, the computer system 26 has a cable 44 that
23 connects it to display console 46 that has one or more
24 display screens. The display console 46 displays data,
25 program steps, and any information required to operate the
26 entire uphole and downhole system. The display console is
27 also connected via cable 48 to alarm and communications
28 system 50 that provides proper notification to crews that
29 servicing is required. Data entry and programming console 52
30 provides means to enter any required digital or manual data,
31 commands, or software as needed by the computer system, and
32 it is connected to the computer system via cable 54.

33
34

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1 In Figure 5, computer system 26 provides commands
2 over cable 56 to the electronics interfacing system 58
3 that has many functions. One function of the electronics
4 interfacing system is to provide information to and from any
5 downhole load through cabling 60 that is connected to the
6 slip-ring 62, as is typically used in the industry.
7 Another function of the electronics interfacing system is to
8 provide power to any downhole load through cabling 60 that is
9 connected to the slip-ring 62. The slip-ring 62 is suitably
10 mounted on the side of the assembled umbilical carousel 64 in
11 Figure 5. Information provided to slip-ring 62 then proceeds
12 to wires A, B, C, D, E, F, and G within the umbilical wound
13 up on the umbilical carousel. The umbilical 66 proceeds to
14 an sheave and tensioner device 68 and then the umbilical
15 proceeds downward at location 70 towards the injection
16 unit and on to the stripper heads and surface blow-out
17 preventers (BOP's). The sheave an tensioner device 68 may
18 place appropriate tension on the umbilical as required.

19
20 In Figure 5, electronics interfacing system 58 also
21 provides power and electronic control of the hydraulic
22 system 72 that controls the umbilical carousel through the
23 connector at location 74. Cabling 76 provides the electrical
24 connection between the electronics interfacing system 58 and
25 the hydraulic system 72 that controls the umbilical carousel.
26 In addition, electronics interfacing system 58 has output
27 cable 78 that provides commands and control to the drilling
28 rig hardware control system 80 that controls various drilling
29 rig functions and apparatus including the rotary drilling
30 table motors, the mud pump motors, the pumps that control
31 cement flow and other slurry materials as required, and all
32 electronically controlled valves, and those functions are
33 controlled through cable bundle 82 which has an arrow on it
34

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1 in Figure 5 to indicate that this cabling goes to these
2 enumerated items.
3

4 In relation to Figure 5, electronics interfacing
5 system 58 also has cable output 84 to ancillary surface
6 transducer and communications control system 86 that provides
7 any required surface transducers and/or communications
8 devices required for communications with the downhole
9 equipment. In a preferred embodiment, ancillary surface and
10 communications system 86 provides acoustic transmitters and
11 acoustic receivers as may be required to communicate to and
12 from certain downhole equipment. The ancillary surface and
13 communications system 86 is connected to the required
14 transducers, etc. by cabling 88 that has an arrow in Figure 5
15 designating that this cabling proceeds to those enumerated
16 transducers and other devices as may be required. Electrical
17 generator 18 provides three phase delta power to variable
18 voltage and frequency converter 20 by cable 90. The output
19 from the voltage and frequency converter 20 is provided by
20 cable 92 to the electronics interfacing system 58. Power to
21 wires A, B, C, D, E, F, and G, and signals to the fiber optic
22 cable 14 (not shown in Figure 5, but which are defined in
23 Figure 1) are provided from the electronics interfacing
24 system 58 through cabling 60 that is connected to the slip-
25 ring 62. The cabling 60 and the slip-ring provide
26 the suitable electrical and fiber optic connections.
27 Cabling 60 possesses connection to wires A, B, C, D, E, F,
28 and G, and to the fiber optic cable 14. In certain preferred
29 embodiments, there are two separated generators and voltage
30 and frequency converters to independently control to first
31 three phase delta system having wires A, B, and C, and the
32 second thee phase delta system having wires D, E, and F.
33
34

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With respect to Figure 5, and to the closed-loop system to drill and complete oil and gas wells, standard electronic feedback control systems and designs are used to implement the entire system as described above, including those described in the book entitled "Theory and Problems of Feedback and Control Systems", "Second Edition", "Continuous(Analog) and Discrete(Digital)", by J.J. DiStefano III, A.R. Stubberud, and I.J. Williams, Schaum's Outline Series, McGraw-Hill, Inc., New York, New York, 1990, 512 pages, an entire copy of which is incorporated herein by reference. Therefore, in Figure 5, the computer system has the ability to communicate with, and to control, all of the above enumerated devices and functions that have been described to this point.

To emphasize one major point in Figure 5, computer system 26 has the ability to receive information from one or more downhole sensors for the closed-loop system to drill and complete oil and gas wells. This computer system executes a sequence of programmed steps, but those steps may depend upon information obtained from at least one sensor located within the downhole system. This computer system provides the automatic control of the umbilical and any uphole and downhole functions related to the deployment of that umbilical.

Figure 6 generally shows the subterranean electric drilling machine 94 that is disposed within a previously installed borehole casing 96 that is surrounded by existing downhole cement 98. The previously installed casing ends at location 100. The inside diameter of the previously installed casing is defined as "ID Casing", but this legend is not shown on Figure 6 for simplicity. The outside diameter of the previously installed casing is defined as

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1 "OD Casing", but this legend is not shown on Figure 6 for
2 simplicity. The wall thickness of the previously installed
3 casing is defined as "WT Casing", but this legend is not
4 shown in Figure 6 for simplicity. The previously installed
5 casing is located within a geological formation 102.

6

7 As shown in Figure 6, the subterranean electric drilling
8 machine is in the process of drilling a new borehole 104 into
9 the geological formation. Pilot bit 106 is shown drilling
10 the pilot hole 108. The OD of the pilot bit is defined as
11 "OD Pilot Bit", but that legend is not shown in Figure 6 for
12 brevity. The ID of the pilot hole is defined as "ID Pilot
13 Hole", but that legend is not shown in Figure 6 for brevity.
14 Undercutters 110 and 112 expand the new borehole to full
15 diameter. The OD of the undercutters 110 and 112 when in the
16 fully extended position is defined as "OD Undercutters", but
17 that legend is not shown in Figure 6 for the purpose of
18 brevity. The overall ID of the new borehole so drilled is
19 defined to be "ID of New Hole", but that legend is not shown
20 in Figure 6 for the purposes of brevity. The pilot bit 106
21 and the undercutters 110 and 112 together form the entire
22 "drill bit" of this assembly. This drill bit is an example
23 of an "expandable drill bit", also called a "retrievable
24 drill bit", that is also called a "retractable drill bit".
25 The following references describe such drill bits: U.S.
26 Patents: U.S. Patent No. 3,552,508, C.C. Brown, entitled
27 "Apparatus for Rotary Drilling of Wells Using Casing as the
28 Drill Pipe", that issued on 1/5/1971, an entire copy of which
29 is incorporated herein by reference; U.S. Patent No.
30 3,603,411, H.D. Link, entitled "Retractable Drill Bits", that
31 issued on 9/7/1971, an entire copy of which is incorporated
32 herein by reference; U.S. Patent No. 4,651,837, W.G.
33 Mayfield, entitled "Downhole Retrievable Drill Bit", that
34 issued on 3/24/1987, an entire copy of which is incorporated

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1 herein by reference; U.S. Patent No. 4,962,822, J.H. Pascale,
2 entitled "Downhole Drill Bit and Bit Coupling", that issued
3 on 10/16/1990, an entire copy of which is incorporated herein
4 by reference; and U.S. Patent No. 5,197,553, R.E. Leturno,
5 entitled "Drilling with Casing and Retrievable Drill Bit",
6 that issued on 3/30/1993, an entire copy of which is
7 incorporated herein by reference. Some experts in the
8 industry call this type of drilling technology to be
9 "drilling with casing". For the purposes herein, the terms
10 "retrievable drill bit", "retrievable drill bit means",
11 "retractable drill bit" and "retractable drill bit means" may
12 be used interchangeably. The combination of the pilot bit
13 and retractable drill bit may also be replaced under certain
14 circumstances with a bicenter drill bit. The retrievable
15 drill bits and the bicenter bits are rotary drill bits.
16

17 When the undercutters 110 and 112 are retracted into
18 their closed positions, then they can be pulled through the
19 unexpanded casing, and then the entire subterranean electric
20 drilling machine can removed from the previously installed
21 casing because in their retracted positions, the OD of the
22 undercutters is less than the ID of the expandable casing
23 and the ID of the previously installed casing. However, when
24 the undercutters are in their extended position as shown in
25 Figure 6, the subterranean electric drilling machine is used
26 to drill the new borehole.

27
28 The downhole electric motor 114 of the subterranean
29 drilling machine obtains its electrical energy from umbilical
30 116. The downhole electric motor 114 is a rotary motor.
31 In one preferred embodiment, the umbilical is the lower end
32 of the particular composite umbilical that is shown in
33 Figure 1. Various electrical wires and connectors along the
34 length of the subterranean electric drilling machine conduct

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1 electrical power from the umbilical to the downhole electric
2 motor (which are designated figuratively by element 118 which
3 is not shown in Figure 6 for the purposes of brevity).
4 Downhole electric motor 114 also possesses internal sensors
5 indicating the voltages between various inputs to the motor,
6 the current drawn by various inputs to the motor, the power
7 consumed by the motor, the temperature of the motor, the RPM
8 of the motor, the torque delivered by the motor, etc. That
9 information is digitized, sent thorough suitable electrical
10 circuitry and connectors along the length of subterranean
11 drilling machine (designated figuratively by element 120
12 which is not shown in Figure 6 for brevity), which digital
13 information is then sent uphole through the fiber optical
14 cable 14 within the umbilical in the form of
15 suitable light pulses. Commands from the surface are also
16 send downhole through the same bidirectional communications
17 path. Such commands including changing RPM of the
18 motor, etc.

19

20 The downhole electric motor has an output shaft which is
21 figuratively designated by element 122, which is not shown in
22 Figure 6 for brevity. Electric motor output shaft 122
23 proceeds through the swivel and seal unit 124 to turn rotary
24 shaft 125 which in turn rotates the undercutters 110 and 112
25 and the pilot bit 106. Rotary shaft 125 is also called the
26 "drilling work string" or simply the "drill pipe". In this
27 preferred embodiment, the undercutters 110 and 112, and the
28 pilot bit 106 comprise the "drill bit". Therefore, in this
29 preferred embodiment, electrical energy provided by umbilical
30 116 to downhole electric motor 114 rotates the drill bit and
31 bores the new borehole 104 into the geological formation.

32

33 In Figure 6, expandable casing 126 generally surrounds
34 rotary shaft 125. Expandable casing is described in various

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1 references in the above section entitled "Description of the
2 Related Art". The initial OD of the expandable casing
3 (before expansion) is defined to be "Initial OD of Expandable
4 Casing", but that legend is not shown in Figure 6 for
5 brevity. The initial ID of the expandable casing (before
6 expansion) is defined to be "Initial ID of Expandable
7 Casing", but that legend is not shown in Figure 6 for
8 brevity. The initial wall thickness of the expandable casing
9 (before expansion) is defined to be the "Initial WT of
10 Expandable Casing", but that legend is not shown in Figure 6
11 for brevity. The length of the expandable casing 126 is
12 defined to be "Length of Expandable Casing", but that legend
13 is not shown in Figure 6 for brevity. The Length of the
14 Expandable Casing can be quite long, and in one preferred
15 embodiment can be at least several thousand feet long. In
16 such a situation, the length of the rotary shaft 125 would be
17 approximately the same length.

18

19 In Figure 6, the length of the submersible electric
20 drilling machine is defined to be "Length of Submersible
21 Electric Drilling Machine", but that legend is not shown in
22 Figure 6 for brevity. The Length of the Expandable Casing
23 can be much longer than the Length of Submersible Electric
24 Drilling Machine. The broken lines 128 in Figure 6 indicate
25 that the Length of the Expandable Casing can be quite long
26 compared to the Length of the Submersible Electric Drilling
27 Machine. The various elements in Figure 6 are not in
28 proportion.

29

30 In Figure 6, the expandable casing 126 is attached to
31 the casing hanger 130. The casing hanger is shown in Figure
32 7, and will be described in detail below. A portion of the
33 casing hanger is surrounded by casing hanger seal 132. The
34 casing hanger setting tool 134 is located within the casing

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1 hanger 130. When the new borehole 104 has been completed,
2 the casing hanger setting tool 134 is used to expand the
3 casing hanger so that it can make positive hydraulic and
4 mechanical contact to the interior of the previously
5 installed downhole casing that is adjacent to the casing
6 hanger seal. Figure 10 below shows the casing hanger after
7 it has been expanded with the casing hanger setting tool, but
8 that will be described in detail in relation to that Figure
9 10. Figure 12 below also shows the casing hanger after it
10 has been expanded with the casing hanger setting tool, but
11 that will be described in detail in relation to that
12 Figure 12.

13

14 Drilling operations typically require means to
15 directionally drill, means to determine the location and
16 direction of drilling, and means to perform measurements of
17 geological formation properties during the drilling
18 operations. Tool section 136 provides the rotary steering
19 device for directional drilling and the LWD/MWD
20 instrumentation packages. Here LWD means "Logging While
21 Drilling" and "MWD" means "Measurement While Drilling".
22 Typically, MWD instrumentation provides at least the location
23 and direction of drilling. The LWD instrumentation provides
24 typical geophysical measurements which include induction
25 measurements, laterolog measurements, resistivity
26 measurements, dielectric measurements, magnetic resonance
27 imaging measurements, neutron measurements, gamma ray
28 measurements; acoustic measurements, etc. This information
29 may be used to determine the amount of oil and gas within a
30 geological formation. Power for this instrumentation is
31 obtained from the umbilical 116.

32

33 In Figure 6, various electrical wires and connectors
34 along the length of the subterranean electric drilling

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1 machine conduct electrical power from the umbilical to the
2 rotary steering device and to the MWD/LWD instrumentation
3 (which are designated figuratively by element 138 which are
4 not shown in Figure 6 for the purposes of brevity). The
5 sensors on the direction steering device and the MWD and LWD
6 instrumentation provide information that is digitized, sent
7 thorough suitable electrical circuitry and connectors along
8 the length of subterranean drilling machine (designated
9 figuratively by element 139 which is not shown in Figure 6
10 for brevity), which digital information is then sent uphole
11 through the fiber optical cable 14 within the umbilical in
12 the form of suitable light pulses. Commands from the surface
13 are also send downhole through the same bidirectional
14 communications path. For example, commands to change the
15 direction of drilling may be sent downhole through this
16 bidirectional communications path.

17
18 In Figure 6, first anchor and weight on bit mechanism
19 (AWOBM) 140 and second anchor and weight on bit mechanism
20 (AWOBM) 142 selectively anchor the subterranean electric
21 drilling machine and provide suitable weight on bit for
22 drilling purposes. First AWOBM possesses anchor means 144
23 and 146. Second AWOBM possesses anchor means 148 and 150.
24 This is an example of a tandem anchor system. In one
25 preferred embodiment, the tandem anchor means 144, 146, 148
26 and 150 are comprised of inflatable packer-like elements.

27
28 In Figure 6, first shaft 152 couples second AWOBM to the
29 downhole electric motor 114. In one preferred embodiment,
30 the first shaft 152 is of fixed length. In another preferred
31 embodiment, first shaft 152 is an extensible shaft. Mud flow
32 channel 154 is shown in Figure 6 that will be more fully
33 described later.

34

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1 In Figure 6, second shaft 156 couples the first AWOBM to
2 the second AWOBM. Second shaft 156 is an extensible shaft.
3 In one preferred embodiment, first AWOBM can move itself with
4 respect to one end of the second shaft 156, and second AWOBM
5 can also move itself with respect to the opposite end of
6 shaft 156. In one embodiment, simple electric motor operated
7 threaded screws and nuts suitably coupled to second shaft 156
8 are used to provide such motion. Those threaded screws,
9 nuts, and electric motors are not shown in Figure 6 for the
10 propose of simplicity. For other examples of related
11 mechanisms, please refer to the following references:

12 (a) Roy Marker, et al., in the paper entitled "Anaconda:
13 Joint Development Project Leads to Digitally Controlled
14 Composite Coiled Tubing Drilling System", SPE 60750,
15 presented at the SPE/ICoTA Coiled Tubing Roundtable,
16 Houston, Texas, April 5-6, 2000, and particularly in
17 Figure 8 entitled "Tractor-driven BHA", an entire copy of
18 which is incorporated herein by reference; and (b) U.S.
19 Patent No. 5,794,703 that issued on August 18, 1998 that is
20 entitled "Wellbore Tractor and Method of Moving an Item
21 Through a Wellbore", an entire copy of which is incorporated
22 herein by reference.

23

24 First anchor and weight on bit mechanism (AWOBM) 140 and
25 second anchor and weight on bit mechanism (AWOBM) 142 provide
26 extension mechanisms with electric powered assemblies that
27 are used to advance the casing and provide bit weight during
28 drilling operations. These mechanisms also resist the
29 drilling torque of the bit by anchoring the rotary motor.
30 In a preferred embodiment, the anchor packers are inflated
31 and deflated with motor driven progressing cavity pumps.
32 Using dedicated PCPs simplifies controls and valves to
33 operate the mechanism.

34

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1 First anchor and weight on bit mechanism (AWOBM) 140 and
2 second anchor and weight on bit mechanism (AWOBM) 142
3 are high strength anchor assemblies which provide axial load
4 capacity at a relative slow axial advance rate. Should the
5 suspended casing weight (in the vertical wellbore) during
6 casing running procedures exceed the umbilical strength
7 rating, then this mechanism may be used to lower the casing
8 into the near horizontal wellbore.
9

10 In Figure 6, various electrical wires and connectors
11 along the length of the subterranean electric drilling
12 machine conduct electrical power from the umbilical to the
13 first anchor and weight on bit mechanism (AWOBM) 140 and to
14 the second anchor and weight on bit mechanism (AWOBM) 142
15 (which are designated figuratively by element 160 which are
16 not shown in Figure 6 for the purposes of brevity). The
17 first anchor and weight on bit mechanism (AWOBM) 140 and
18 second anchor and weight on bit mechanism (AWOBM) 142 have
19 many sensors including force sensors, torque sensors,
20 position sensors, speed sensors, etc. Information from these
21 sensors are sent thorough suitable electrical circuitry and
22 connectors along the length of subterranean drilling machine
23 (designated figuratively by element 162 which is not shown in
24 Figure 6 for brevity), which digital information is then sent
25 uphole through the fiber optical cable 14 within the
26 umbilical in the form of suitable light pulses. Commands
27 from the surface can also be sent downhole through this
28 bidirectional communications path. For example, detailed
29 commands can be sent to change the locations of first AWOBM
30 140 and second AWOBM 142 or to change the effective load
31 placed on the drilling bit by these mechanisms.
32

33 In Figure 6, first mud cuttings and bypass port
34 (MCBP) 164 allows mud and drill cuttings to pass by the

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1 first AWOBM 140. Second mud cutting and bypass port
2 (MCBP) 166 allows mud and drill cutting to pass by the second
3 AWOBM 142. These are electrically operated ports. Various
4 electrical wires and connectors along the length of the
5 subterranean electric drilling machine conduct electrical
6 power from the umbilical to the first MCBP and to the second
7 MCBP (which are designated figuratively by element 168 which
8 are not shown in Figure 6 for the purposes of brevity). The
9 first MCBP and to the second MCBP have many sensors providing
10 temperature, pressure, etc. The information from these
11 sensors are sent through suitable electrical circuitry and
12 connectors along the length of subterranean drilling machine
13 (designated figuratively by element 170 which is not shown in
14 Figure 6 for brevity), which digital information is then sent
15 uphole through the fiber optical cable 14 within the
16 umbilical in the form of suitable light pulses. Commands
17 from the surface can also be sent downhole through this
18 bidirectional communications path. For example, detailed
19 commands can be sent to close first MCBP and to the second
20 MCBP to prevent a well blow-out.
21

22 In Figure 6, mud carrying shaft 172 is attached to the
23 first AWOBM by housing 174. The female side of universal mud
24 and electrical connector 176 is attached to the male side of
25 universal mud and electrical connector 178. Progressing
26 cavity pump 180 is driven by a downhole pump motor assembly
27 generally designated by element 182. A progressing cavity
28 pump is abbreviated as a "PCP". Progressing cavity pump 180
29 also includes an integral flexible shaft as is typical in the
30 industry. In one preferred embodiment, the downhole pump
31 motor assembly generally designated by element 182 is
32 comprised of protector 184; first 80 horsepower electric
33 motor 186 requiring 1250 volts at 45 amps that runs at the
34 nominal RPM of 1700 RPM; second 80 horsepower electric motor

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1 188 requiring 1250 volts at 45 amps that also runs at the
2 nominal RPM of 1700 RPM; universal motor base 190; gearbox
3 protector 192; and gearbox 194 having a 4:1 reduction. The
4 downhole pump motor assembly and a portion of the progressing
5 cavity pump 180 is covered by shroud 196.

6
7 Various electrical wires and connectors along the length
8 of the subterranean electric drilling machine conduct
9 electrical power from the umbilical to the downhole pump
10 motor assembly (which are designated figuratively by element
11 198 which are not shown in Figure 6 for the purposes of
12 brevity). The subterranean electric drilling machine has
13 many sensors including voltage sensors, current sensors,
14 torque sensors, temperature sensors, RPM sensors, etc. The
15 information from these sensors are sent thorough suitable
16 electrical circuitry and connectors along the length of
17 subterranean drilling machine (designated figuratively by
18 element 200 which is not shown in Figure 6 for brevity),
19 which digital information is then sent uphole through the
20 fiber optical cable 14 within the umbilical in the form of
21 suitable light pulses. Commands from the surface can also be
22 sent downhole through this bidirectional communications path.
23 For example, detailed commands can be sent to change the
24 the RPM of first electric motor 186 and second electric
25 motor 188.

26
27 Figure 6 also shows three-way valve 202. This three-way
28 valve is used to change the direction of mud flow inside the
29 subterranean electric drilling machine. The functions of the
30 three way 202 valve will be described below.

31
32 Figure 6 also shows umbilical mud valve 204. This mud
33 valve is used to shut off mud flow, or otherwise prevent well
34 blow-outs. The mud valve 204 has a total of three positions:

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1 (a) open, namely it allows mud to flow through as shown in
2 Figure 6; (b) stop (not allow any mud to flow straight
3 through); and (c) vent to the annulus between the umbilical
4 116 and the ID of the previously installed casing 212 so that
5 cement or cuttings can be cleaned from within the umbilical
6 (which state is not shown in Figure 6 for simplicity).
7

8 Various electrical wires and connectors along the length
9 of the subterranean electric drilling machine conduct
10 electrical power from the umbilical to three-way valve 202
11 and to the umbilical mud valve 204 (which are designated
12 figuratively by element 206 which are not shown in
13 Figure 6 for the purposes of brevity). The three-way valve
14 202 and the umbilical mud valve 204 possess many sensors
15 including pressure sensors, voltage sensors, current sensors,
16 and temperature sensors, etc. The information from these
17 sensors are sent thorough suitable electrical circuitry and
18 connectors along the length of subterranean drilling machine
19 (designed figuratively by element 208 which is not shown in
20 Figure 6 for brevity), which digital information is then sent
21 uphole through the fiber optical cable 14 within the
22 umbilical in the form of suitable light pulses. Commands
23 from the surface can also be sent downhole through this
24 bidirectional communications path. For example, detailed
25 commands can be sent to change set the three-way valve 202
26 into any position, or to close, or open, umbilical valve 204.
27

28 In addition, Smart Shuttle™ seal 210 is shown in
29 Figure 6. Smart Shuttle seal 210 is attached to a portion of
30 shroud 180. For the purposes of succinct reference within
31 this disclosure, the above entire list of Provisional Patent
32 Applications, the U.S. Patents that have issued, the Pending
33 U.S. Patent Applications that appear under the title of
34 "Cross-References to Related Applications", the foreign

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1 pending Patent Applications under "Related PCT Applications",
2 and the above U.S. Disclosure Documents under of "Related
3 U.S. Disclosure Documents", all having William Banning Vail
4 III as at least one of the inventors, is owned by the firm
5 Smart Drilling and Completion, Inc. ("SDCI"), and therefore
6 this intellectual property is defined herein to be the "SDCI
7 Intellectual Property" or simply "SDCI IP" as an
8 abbreviation. Smart Drilling and Completion, Inc. may be
9 reached at 3123 - 198th Place S.E., Bothell, Washington
10 98012, having the telephone number of (425) 486-8789, that
11 has the website of www.Smart-Drilling-and-Completion.com.
12 The Smart Shuttle is extensively described in the above
13 defined "SDCI IP". The principal of operation of the Smart
14 Shuttle is also described below in relation to Figure 24.
15 The shroud 196 extends to the left in Figure 6 so that the
16 Smart Shuttle™ seal 210 is installed on a portion of that
17 shroud.

18

19 In a preferred embodiment shown in Figure 6. A reverse
20 mud circulation system has been configured with the umbilical
21 in the wellbore. Fresh mud travels from the surface down the
22 annuli between the well casing and the umbilical designated
23 by element 212. The right-hand side of Figure 6 is "down" in
24 Figure 6. Fresh mud travels down from the surface as
25 indicated by various arrows throughout the subterranean
26 drilling machine. Clean mud then flows through the interior
27 of the shroud 214 to the three-way valve 202. In one
28 preferred embodiment, the three-way valve directs mud into
29 the input of the progressing cavity pump so that the pump
30 boosts the pressure of the mud delivered to the drill bit.
31 This is called "Position A" of the three-way mud valve. The
32 detailed tubing and other hardware necessary to accomplish
33 the details of "Position A" is not shown in Figure 6 for the
34 purpose of simplicity. In "Position A", clean mud then flows

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1 through the interior of the male side of universal mud and
2 electrical connector 178; then through the female side of
3 universal mud and electrical connector 176; then through mud
4 carrying shaft 172; then through mud flow channel 158; then
5 through the interior of second shaft 156; then through mud
6 flow channel 154; then through the interior of first shaft
7 152; then through the swivel and seal unit 124; then through
8 rotary shaft 125; and then through the mud channels in pilot
9 bit 108.

10

11 In Figure 6, cuttings laden mud then returns to the
12 surface through the following path. The cuttings laden mud
13 flows up between the outside diameter of the expandable
14 casing 126 and the inside diameter of the new borehole 104;
15 then through the second mud cutting and bypass port (MCBP)
16 166; then through the first mud cuttings and bypass port
17 (MCBP) 164; then through the volume between the exterior of
18 the shroud 196 and the ID of the previously installed
19 borehole casing 96; then through cross-over system 216; and
20 then into umbilical 116 and through the umbilical mud valve
21 204 and then to the surface of the earth through the
22 remainder of the umbilical disposed in the wellbore.

23

24 Cuttings laden mud returns to the surface flowing
25 through the ID of the umbilical. The purpose is to keep the
26 wellbore clean. The subterranean electric drilling machine
27 94 may be recovered to the surface while cuttings and mud
28 fill the umbilical. Time to circulate the umbilical clean is
29 not needed prior to tripping out of the hole.

30

31 In the preferred embodiment illustrated in Figure 6, the
32 clean mud is provided a booster pressure to improve bit
33 hydraulics. If a bit is selected that produces fine
34 cuttings, the PCP mud pump is compatible with pumping the

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1 cuttings filled mud. In an alternative design, the benefit
2 for pumping the cuttings is a reduction in backpressure held
3 on the geological formation.

4

5 In Figure 6, there are two other positions of the three
6 way-valve 202, "Position B", and "Position C". In
7 "Position B" of the three-way valve, the PCP pump 180 is not
8 used to boost the mud pressure delivered through the mud
9 channels of the pilot bit 108. Here, clean mud flows through
10 the interior of the shroud 214 to the three-way valve 202,
11 and then directly into the male side of universal mud and
12 electrical connector 178 and through the remaining portions
13 of the subterranean electric drilling machine to the mud
14 channels of the pilot bit 108. The detailed configuration of
15 pipes and other related hardware to accomplish this mode of
16 operation is not shown in Figure 6 for the purpose of
17 brevity.

18

19 In Figure 6, Position C of the three-way valve 202
20 allows the entire subterranean drilling machine to move
21 within the previously installed borehole casing 96. The
22 fluid filled region defined between the subterranean drilling
23 machine and the interior of the previously installed borehole
24 casing is designated by element 218 in Figure 6. As
25 previously stated, the fluid filled region defined between
26 the inside of the previously installed casing and the outside
27 diameter of the umbilical, which is the annuli between the
28 well casing and the umbilical, is designated by element 212.
29 In "Position C" of the three-way valve 202, fluids are pumped
30 from the region 218 into region 212. If there is a good seal
31 between the exterior of the umbilical and the borehole at the
32 surface produced by the stripper heads and surface blow-out
33 preventers (BOP's), then the existence of the Smart Shuttle™
34 seal 210 causes the subterranean drilling machine to go down

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1 into the well. Reversing the PCP, causes the subterranean
2 electric drilling machine to reverse direction. For a more
3 detailed description of the operation of a Smart Shuttle,
4 please refer to the above defined "SDCI IP", entire copies of
5 which are incorporated herein by reference. "Position C" of
6 the three-way valve 202 provides an important function to
7 rapidly trip the subterranean electric drilling machine to
8 the surface and back should any drilling component need
9 maintenance or replacement. This capability provides
10 operational flexibility for the system. Based upon existing
11 designs with currently available downhole electric motors and
12 progressing cavity pumps, practical speeds of 10 feet per
13 second can be anticipated while pulling a load of at least
14 4,000 lbs.

15

16 In Figure 6, the fluid filled region between the casing
17 hanger seal 132 and the pilot bit 106 is designated by
18 element 220. During drilling operations, the mud pressure in
19 region 212 is defined to be P1; the mud pressure in the
20 interior of the shroud defined by element 214 is P2; the mud
21 pressure at the input to the three-way valve 202 is P3; the
22 mud pressure within the male side of universal mud and
23 electrical connector 178 is P4; the mud pressure inside the
24 mud channels of the pilot bit 108 is P5; the pressure within
25 region 220 is P5; the pressure within region 218 is P6; and
26 the pressure within the umbilical 116 is P6.

27

28 The subterranean electric drilling machine in
29 Figure 6 provides other benefits. Since the anchor points
30 secure the drilling machine in the well's casing and mudflow
31 paths must pass through valves within the machine, the entire
32 unit serves the function of a downhole packer with safety
33 valve and serves as a BOP located downhole, or Downhole BOP™.
34 The BOP is comprised of first mud cuttings and bypass port

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1 (MCBP) 164, second mud cutting and bypass port (MCBP) 166,
2 and the umbilical mud valve 204 provide the required
3 functions of a BOP located downhole.

4

5 It is also worthwhile to make a few more comments about
6 the downhole electric motor 114. This electric motor rotates
7 the drilling bit. This electric motor may possess a gearbox
8 to match the bit's speed requirements. Monitoring the
9 motor's power, RPM, torque, current drawn, voltage drawn
10 etc., provides significant information about the condition of
11 the bit and its drilling performance. As one particular
12 example, the electric motor is chosen to be a REDA
13 4 pole, 80 horsepower, electric motor requiring 1250 volts
14 at 45 amps that runs at the nominal RPM of 1700 RPM that
15 is 5.4 inches OD and 31.5 inches long. The RPM of this motor
16 may be conveniently varied by varying the frequency of the
17 voltage applied to it as is indicated by Figure 2 and the
18 related description. In one preferred embodiment, the RPM of
19 the electric motor in the subterranean electric drilling
20 machine is varied between about 900 RPM to 2,500 RPM.
21 In this one preferred embodiment, the particular REDA motor
22 does not need a gearbox for this application. In another
23 preferred embodiment, two such REDA motors are operated in
24 series that provide a net downhole motor capable of providing
25 160 horsepower to a rotating drill bit at the rotation speed
26 between 900 RPM and 2,500 RPM. The RPM and other parameters
27 of the downhole motor are controlled by computer system 26 in
28 Figure 5. Another preferred embodiment uses the electric
29 motor described in U.S. Disclosure Document No. 498,720 filed
30 on August 17, 2001 that is entitled in part "Electric Motor
31 Powered Rock Drill Bit Having Inner and Outer Counter-
32 Rotating Cutters and Having Expandable/Retractable Outer
33 Cutters to Drill Boreholes into Geological Formations",
34 an entire copy of which is incorporated herein by reference.

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1 The drilling fluid transitions from a nonrotating
2 element which is first shaft 152, into a rotating pipe that
3 is rotary shaft 125. The swivel and seal unit 124
4 prevents fluid leaks in this area. Unlike a swivel-packing
5 gland, this seal operates at a relative low differential
6 pressure. Suitable rotating seal assemblies are commercially
7 available for these conditions. Electric power and
8 communications from the fixed (non-rotating) components to
9 the rotating assembly is required. An inductive connection
10 or a slip-ring assembly will provide the power, communication
11 and control linkage through the swivel and seal unit 124 to
12 the fiber optic communication system and the power available
13 through the umbilical. However, the details for either the
14 inductive connection or slip-ring assembly are not shown in
15 Figure 6 in the interests of simplicity.

16

17 Figure 6 as described above drills the borehole with the
18 long section of expandable casing 126 carried into the new
19 hole 104 as the new hole is drilled. However, in
20 an alternative preferred embodiment, a short section of
21 expandable pipe 126 is used to drill the borehole, then the
22 subterranean electric drilling machine is retrieved from the
23 wellbore, and then that machine conveys into the well the
24 long section of expandable casing 126 to be cemented and
25 expanded into place within the new borehole 104.

26

27 Figure 6 as described, uses the pilot bit 106 and the
28 two undercutters 110 and 112 as the "drill bit" to drill the
29 new borehole 104. However, a bicenter bit as is used in the
30 industry could also be used as the "drill bit" in Figure 6,
31 provided it had suitable dimensions to be withdrawn through
32 the ID of the unexpanded state of the expandable casing 126,
33 and through the interior of the previously installed borehole
34 casing 96.

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1 In relation to Figure 1, wires A, B, and C comprise the
2 first independent three phase delta circuit. Wires D, E, and
3 F comprise the second independent three phase delta circuit.
4 Each separate circuit is capable of providing 160 horsepower
5 (119 kilowatts) over an umbilical length of 20 miles.
6 In relation to Figure 6, and in one preferred embodiment, the
7 first independent three phase delta circuit provides up to
8 160 horsepower to the downhole electric motor 114. In
9 relation to Figure 6, and in one preferred embodiment, the
10 second independent three phase delta circuit provides up to
11 160 horsepower to the downhole pump motor assembly 182 in
12 Figure 6. In one preferred embodiment, each first and second
13 circuit are independently controlled. So, combined, the
14 umbilical shown in Figure 1 can deliver a total of 320
15 horsepower (238 kilowatts) at 20 miles to do work at that
16 distance.

17

18 **Figure 7** shows the casing hanger 130. The casing hanger
19 was identified with element 130 in Figure 6. A portion of
20 the casing hanger is surrounded by casing hanger seal 132.
21 The casing hanger seal was also previously identified with
22 element 132 in Figure 6.

23

24 The expandable casing 126 shown in Figure 6 is attached
25 to the casing hanger 130. In one embodiment, the casing
26 hanger is attached to the expandable casing by a threaded
27 joint. In this embodiment, that threaded joint appears at
28 end of casing hanger 222, although the threads on the casing
29 hanger are not shown in Figure 7 for simplicity. The
30 opposite end of the casing hanger is shown as element 223.
31 In another preferred embodiment, the casing hanger can be
32 manufactured integral with the expandable casing. A cement
33 flowby port 224 is used during the cementing process as
34 further explained in relation to Figure 10. The expandable

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1 hanger contact area is generally designated as element 226
2 in Figure 7. The length of the expandable hanger contact
3 area is designated by the legend L1 in Figure 7.

5 **Figure 8** shows more detail for the downhole pump motor
6 assembly that is related to element 182 in Figure 6.
7 Elements 180, 184, 186, 188, 190, 192 and 194 were previously
8 identified in Figure 6. Those same elements are related to
9 the elements appearing in the following.

10
11 Figure 8 generally shows a downhole pump motor assembly
12 identified as element 228 which is configured as a Smart
13 Shuttle™. In one preferred embodiment, various parts from
14 REDA are used to make a downhole pump motor assembly 182.
15 REDA may be located as defined above. In the embodiment,
16 element 230 is a REDA protector for a bottom drive motor that
17 is 5.4 inches OD, and 4.5 feet long. In this embodiment,
18 element 232 is a first REDA 4 pole, 80 horsepower, electric
19 motor requiring 1250 volts at 45 amps that runs at the
20 nominal RPM of 1700 RPM that is 5.4 inches OD and 31.5 inches
21 long. Element 234 is a power cable providing electrical
22 power to the downhole pump motor assembly 228. In this
23 embodiment, element 236 is a second REDA 4 pole, 80
24 horsepower, electric motor requiring 1250 volts at 45 amps
25 that runs at the nominal RPM of 1700 RPM that is 5.4 inches
26 OD and 31.5 inches long. Element 238 is a REDA universal
27 motor base part number UMB-B1 for a bottom drive motor that
28 is 5.4 inches OD and 1.7 feet long. Element 240 is REDA
29 gearbox protector part number BSBSB having 4 mechanical seals
30 that is 5.4 inches OD and 10.6 feet long. Element 242 is a
31 REDA gearbox having a 4:1 gear reduction that is 6.8 inches
32 OD and 10.9 feet long. Element 244 is a Netzsch flexible
33 shaft that is 7.87 inches OD and 10 feet long. Netzsch
34 Oilfield Products is located at 119 Pickering Way, Exton,

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1 Pennsylvania 19341, having the telephone number of (610)
2 363-8010, that has the website of www.netzchusa.com.
3 Element 248 is a Netzschr progressing cavity pump part number
4 NM090*3L (EX) that is 7.87 inches OD and 11.8 feet long.
5 Element 248 is a crossover. Element 250 is 4 inch tubing.
6 Element 252 is a Smart Shuttle seal. Element 254 is an
7 intake port into the Netzschr progressing cavity pump.
8 Element 256 is the discharge outlet from the Netzschr
9 progressing cavity pump.

10
11 The downhole pump motor assembly identified as element
12 228 needs a cablehead, centralizers, bypass valves, sensors,
13 and intelligent controls to make one embodiment of a Smart
14 Shuttle™. Such a Smart Shuttle will have a minimum pulling
15 force of 4400 lbs, a maximum transit speed of 11 feet per
16 second, that operates within 9 5/8 inch O.D., 53.5 lb/foot
17 casing. It has variable speed, is reversible, and has high
18 speed bidirectional communications with instrumentation on the
19 surface of the earth.

20
21 **Figure 9** shows a subterranean electric drilling machine
22 boring a new borehole from an offshore platform. Figure 9
23 shows the subterranean electric drilling machine 94 deployed
24 within a previously installed borehole casing 96 that is
25 surrounded by existing downhole cement 98 that is in the
26 process of drilling the new borehole 104 into geological
27 formation 102, which elements were previously defined in
28 relation to Figure 6. Also shown in Figure 9 is the
29 expandable casing 126 that was also defined in
30 Figure 6. The subterranean electric drilling machine was
31 thoroughly described in Figure 6.

32
33 In Figure 9, an offshore platform 258 has a hoisting
34 mechanism 260 that is surrounded by ocean 262 that is

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1 attached to the bottom of the ocean 264. The ocean surface
2 is shown by element 265. Riser 266 is attached to blow-out
3 preventer 268. Surface casing 270 is cemented into place
4 with cement 272. A section of previously installed casing
5 274 extends from the lower portion of the surface casing 270
6 to the previously installed borehole casing 96. The broken
7 line 276 shows that the section of previously installed
8 casing 274 can be many thousands of feet long. Previously
9 installed casing 274 may actually be comprised of different
10 lengths of casings having different inside diameters, outside
11 diameters, and weights, but that detail is not shown in
12 Figure 9 in the interest of simplicity. Other conductor
13 pipes, surface casings, intermediate casings, liner strings,
14 or other pipes may be present, but they are not shown for
15 simplicity. The upper portion of the umbilical 278 proceeds
16 to the stripper heads and surface blow-out preventers
17 (BOP's), then proceeds to location 70 in Figure 5, and
18 is then wound up on the umbilical carousel 64 in
19 Figure 5. In this preferred embodiment, the computerized
20 uphole management system for the umbilical as shown Figure 5
21 is mounted on the offshore platform. In Figure 9, other
22 geological formations represented by element 280 are located
23 above geological formation 102. Other geological formations
24 represented by element 282 are below geological
25 formation 102.

26

27 In Figure 9, the directions of the arrows show the mud
28 flow. Fresh mud travels from the surface down the annuli
29 between the well casing and the umbilical designated by
30 element 212. Element 212 was previously defined in
31 Figure 6. Cuttings laden mud returns to the offshore
32 platform 258 on the interior of the umbilical 283. The
33 arrows show the mud flow pattern in the vicinity of the
34 subterranean electric drilling machine 94. This mud flow

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1 system is called a "reverse mud flow system". This reverse
2 mud flow system will keep the cuttings within the umbilical,
3 therefore preventing any debris from accumulating in the
4 annuli between the well casing and the umbilical that might
5 prevent the subterranean electric drilling machine from
6 returning to the offshore platform. In other preferred
7 embodiments, the mud flow can be opposite - namely, clean mud
8 flows down the interior of the umbilical, and cuttings laden
9 mud flows up the annuli between the well casing and the
10 umbilical.

11

12 For the purposes of this invention, the phrase
13 "offshore platform" includes the following: (a) bottom
14 anchored structures that include artificial islands, gravity
15 based structures, piled truss structures (conventional
16 platforms), and compliant towers; (b) mobile-bottom sitting
17 structures that include submersible structures including
18 submersible barges (in swampy and shallow water areas),
19 mobile gravity base structures (like the concrete islands
20 in the Arctic) and jackup platforms; (c) floating-permanently
21 moored structures including the tension leg platforms (TLP),
22 the SPAR and Semisubmersible, and the Floating Production,
23 Storage, and Offloading structures (FPSO); and (d) floating-
24 mobile structures such as shipshape-like drilling rigs,
25 semisubmersibles that are catenary moored, and barges.

26

27 It is helpful to review how Figures 6, 7, 8, and 9
28 relate to the drilling process. As was shown in Figure 6,
29 the expandable casing 126 in its un-expanded state is carried
30 into the hole as an outer sheath over rotary shaft 125 and
31 associated components, which may also be called a "drilling
32 work string". At the lower end of that borehole assembly
33 ("BHA") is anchored into the casing. In one preferred
34 embodiment, the string of expandable casing is 3,000 ft long.

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1 Starting with the drilling machine out of the hole, the
2 expandable casing is run in and suspended in the wellbore
3 from the surface. The top of the casing has an expandable
4 casing hanger installed. Figure 7 shows the expandable
5 casing hanger. Next, the bottom hole assembly is run through
6 the casing and secured into the bottom joint of the
7 unexpanded suspended casing. The casing hanger setting tool
8 134 is secured into the casing hanger 130 together with the
9 first and second anchor and weight on bit mechanisms 140 and
10 142, the downhole electric motor 114, and the remaining
11 portions of the subterranean electric drilling machine 94.
12 The entire subterranean electric drilling machine and
13 expandable casing is then tripped to the bottom of the well.
14 Drilling the next section of the well continues until
15 sufficient hole for the expandable casing has been drilled.
16 With the expandable casing in place, the casing hanger
17 setting tool expands and locks the unexpanded length of
18 expandable casing in the hole. The subterranean electric
19 drilling machine 94 then releases from the casing and is
20 recovered from the well.

21

22 In one preferred embodiment, the casing hanger setting
23 tool 134 is a packer-like assembly located beneath the
24 downhole electric motor 114. The casing hanger setting tool
25 initially expands with sufficient pressure to secure the
26 casing to the non-rotating housing that is connected to the
27 swivel and seal unit 124 that centralizes the casing. Once
28 the new hole has been drilled, and the casing hanger 130 is
29 in proper setting position, much higher pressure is pumped
30 into the casing hanger setting tool to plastically expand the
31 hanger and cold forge the hanger into the previously
32 installed borehole casing 96. As an example of this process,
33 various manufacturers connect pipeline repair tools to
34 pipeline ends and connect wellheads to the top of casing

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1 strings with this type of "cold forge" process. The cement
2 flowby ports of the casing hanger are left open for
3 circulation of cement behind the casing. When the expandable
4 casing is later expanded, these holes are sealed through
5 contact with overlap in the previous casing string. The
6 casing hanger seal and cement help ensure a leak tight seal.
7

8 In one preferred embodiment of the invention, the
9 subterranean electric drilling machine is used to accomplish
10 the many purposes including the following: (a) drill the new
11 borehole 104; (b) convey into the well the expandable casing
12 126; and (c) then using the casing hanger setting tool 134,
13 the casing hanger is expanded into the previously installed
14 borehole casing 96. Thereafter, the subterranean electric
15 drilling machine releases from the casing hanger, thereby
16 leaving the casing hanger and the expandable casing 126 in
17 its unexpanded state in the well, and the subterranean
18 electric drilling machine is then removed from the well.
19

20 Thereafter, another tool called a subterranean liner
21 expansion tool is conveyed into the wellbore. In one
22 preferred embodiment, the subterranean liner expansion tool
23 is labeled with element 284 in Figure 10. Figure 10 shows
24 the previously installed borehole casing 96, the existing
25 downhole cement 98, the new borehole 104, a portion the
26 casing hanger 130 after the above expansion steps have been
27 performed in (c) above, one end 222 of the casing hanger
28 shown in Figure 7, and the other end 223 of the casing hanger
29 shown in that figure. Cement flowby port 224 is also shown.
30

31 The subterranean liner expansion tool 284 is used in a
32 two step process. First, the cement is injected behind the
33 unexpanded expandable casing. That process is shown in
34 Figure 10. Second, the expandable casing is expanded. That

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1 process is shown in Figure 11. Thereafter, the subterranean
2 liner expansion tool is removed from the well, and the well
3 is either completed, or the well is further extended using
4 the methods and apparatus described above.

5

6 In Figure 10, the subterranean liner expansion
7 tool 284 is positioned within unexpanded casing 286.
8 Counter-rotating roller casing expander tool is generally
9 shown as numeral 288 in Figure 10. In one preferred
10 embodiment, clockwise rotating roller assembly 290 is on the
11 uphole side of the counter-rotating roller casing expander
12 tool. It has individual rollers 292, 294, 296, and 298. In
13 this embodiment, counter-clockwise rotating roller assembly
14 300 is on the downhole side counter-rotating roller casing
15 expander tool. It has individual rollers 302, 304, 306 and
16 308. Electrically powered hydraulic systems within the
17 counter-rotating roller casing expander tool are capable of
18 loading the individual rollers against the interior of the
19 expandable casing. In one preferred embodiment, several of
20 the rollers, such as roller 304, are canted through the
21 angel θ . In one preferred embodiment, the rollers are
22 hydraulically loaded and are canted to advance through the
23 expandable casing as the rotating roller assemblies 290 and
24 300 rotate in their respective directions. Electrically
25 powered systems within the counter-rotating roller casing
26 expander tool are then capable of rotating the appropriate
27 elements of each rotating roller assembly. In Figure 10, the
28 rollers are in their fully retracted position. The electric
29 motor and related hydraulics for the counter-rotating roller
30 casing expander tool are located within housing 310. That
31 electric motor is labeled with legend 312, and the related
32 hydraulics is labeled with legend 314, although those are not
33 shown in Figure 10 for simplicity.

34

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1 The torque resistance section 316 is a component of the
2 counter-rotating roller casing expander. It has longitudinal
3 rollers 318 and 320. An electric motor 322 and associated
4 hydraulics 324 are located within torque resistance section
5 316 to properly actuate the longitudinal rollers 318 and 320.
6 However, elements 322 and 324 are not shown in Figure 10 for
7 the purposes of simplicity. The purpose of the torques
8 resistance section 316 is to prevent any unbalanced torque
9 resulting from the operation of the subterranean liner
10 expansion tool that might cause the remainder of the downhole
11 tool attached to the umbilical 116 to twist, thereby possibly
12 breaking the umbilical. Breaking the umbilical downhole
13 would be a catastrophic failure, although the tool can be
14 retrieved using techniques to be described below.

15

16 Various electrical wires and connectors along the length
17 of the subterranean liner expansion tool conduct electrical
18 power from the umbilical 116 to the counter-rotating roller
19 casing expander tool 288 (which are designated figuratively
20 by element 326 which are not shown in Figure 6 for the
21 purposes of brevity). Sensors within the counter-rotating
22 roller casing expander tool provide measurements such as the
23 force delivered by the rollers to the casing, the position of
24 the rollers, etc., which measurements are suitably is
25 digitized and sent thorough suitable electrical circuitry and
26 connectors along the length of subterranean liner expansion
27 tool (designated figuratively by element 328 which is not
28 shown in Figure 10 for brevity), which digital information is
29 then sent uphole through the fiber optical cable 14 within
30 the umbilical 116 in the form of suitable light pulses.
31 Commands from the surface are also send downhole through the
32 same bidirectional communications path. For example,
33 commands to change the contact of the rollers, or expand the
34

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1 rollers outward to expand the casing may be sent downhole
2 through this bidirectional communications path.
3

4 Figure 10 further shows progressing cavity pump 180 that
5 is driven by a downhole pump motor assembly 182 and shroud
6 180, which were previously described in Figure 6. Inflatable
7 cement seal 330 is inflated during cementing operations.
8

9 In the preferred embodiment shown in Figure 10, cement
10 from the surface proceeds through umbilical 116; through
11 umbilical mud valve 204 (which is used for both mud and
12 cementing purposes); to the cross-over system 216 and into
13 region 332; through the cement flowby port 224; through
14 region 334 between the previously installed borehole casing
15 96 and the exterior of the unexpanded casing 286; then into
16 region 336 between the exterior of the unexpanded casing and
17 the ID of the new borehole that labeled with element 338.
18 The mud valve 204 has a total of three positions:

19 (a) open, namely it allows cement to flow through as shown in
20 Figure 10; (b) stop (not allow any cement to flow straight
21 through); and (c) vent to the annulus between the umbilical
22 116 and the ID of the previously installed casing so that
23 cement can be cleaned from within the umbilical (which state
24 is not shown in Figure 10 for simplicity). The region
25 between the umbilical 116 and the ID of the previously
26 installed casing is shown a element 212 in Figure 6, although
27 that particular element is not shown in Figure 10 for
28 simplicity (because of the large number of labeled elements
29 in that vicinity of Figure 10).
30

31 In Figure 10, the position of the "front" of the cement
32 flow is shown by element 340. Sufficient cement is
33 introduced into region 336 so that when the unexpanded casing
34 286 is expanded in the next step (as explained below), then

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1 the well is properly cemented in place. Various sensors
2 within the subterranean liner expansion tool provide data
3 that allows the computer system 26 on the offshore platform
4 in this embodiment to determine the proper amount of cement
5 to be sent downhole that at least partially fills region 342
6 that is located between the exterior of the unexpanded casing
7 286 and OD of the new borehole 338 which is not filled with
8 cement in Figure 10. The overlapping region between the old
9 cement and the new cement that has not set up in Figure 10 is
10 shown as element 344. The new cement is now allowed to set
11 up as shown in Figure 10. However, there is old cement that
12 is hardened in Figure 10 such as the old cement behind the
13 casing hanger 130 that is identified with numeral 345.

14

15 The subterranean liner expansion tool 284 is comprised
16 of a number of components including the counter-rotating
17 roller casing expander tool 284 and the Smart Shuttle™.
18 The subterranean liner expansion tool is transported downhole
19 by the Smart Shuttle™ which is comprised of components
20 including the Smart Shuttle™ seal 210, the progressing cavity
21 pump 180, the downhole pump motor assembly 182, and the
22 shroud 180 which have been previously described in relation
23 to Figure 6. The Smart Shuttle also returns the subterranean
24 liner expansion tool to the offshore platform in this
25 preferred embodiment.

26

27 In a preferred embodiment of the invention shown in
28 Figure 10, the unexpanded casing 286 is 3,000 feet long, has
29 a weight of approximately 40 lbs/foot, and has an unexpanded
30 OD of approximately 8.0 inches OD. In a preferred embodiment
31 shown in Figure 10, the previously installed borehole
32 casing 96 is a 9 5/8 inch OD casing having a weight of
33 approximately 40 lbs/foot.

34

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1 **Figure 11** shows the subterranean liner expansion tool
2 284. Portions of the subterranean liner expansion tool are
3 shown in Figure 11 including the counter-rotating roller
4 casing expander tool 288, the torque resistance section 316,
5 and the progressing cavity pump 180 that is attached to the
6 downhole pump motor assembly 182.

7
8 After cementing was completed in Figure 10, the
9 subterranean liner expansion tool is pulled up vertically
10 above the casing hanger 130. Then the rollers of the
11 the clockwise rotating roller assembly 290 the counter-
12 clockwise rotating roller assembly 300 are placed in their
13 extended positions. Then counter-rotating roller casing
14 expander tool 288 is suitably energized, and it begins to
15 expand the expandable casing on its downward travel (to the
16 right-hand side of Figure 11) within the well. Figure 11
17 shows the subterranean liner expansion tool in a location in
18 the formation that is beyond the end of the previously
19 installed casing 100 that is defined in Figure 10.
20

21 In Figure 11, the expandable casing in its fully
22 expandable form is shown at location 348. In Figure 11, the
23 expandable casing in its unexpanded form is shown at location
24 350. Cement surrounding the expandable casing in its fully
25 expandable form is shown as element 352 in Figure 11. Cement
26 surrounding the expandable casing in its unexpanded form is
27 shown as element 354 in Figure 11. The counter-rotating
28 roller casing expander tool 288 remains suitable energized,
29 and it eventually completes the expansion of the expandable
30 casing at some extreme distance in the well designed by
31 element 356 in Figure 11. Thereafter, the liner expansion
32 tool 284 is removed from the wellbore. Thereafter, the
33 cement is allowed to cure. After the cement is cured, the
34 well is completed to produce oil and gas using techniques and

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1 procedures typically used in the oil and gas industry or
2 using those methods and apparatus described in the "SDCI IP",
3 entire copies of which are incorporated herein by reference.

4
5 In Figure 11, the expandable casing in its fully
6 expandable form as shown at location 348 can also be called
7 equivalently a "liner" because of its attachment to the
8 previously installed casing 96 in Figure 10. Hence, the name
9 "subterranean liner expansion tool".

10
11 **Figure 12** shows the casing hanger 130, a cement flowby
12 port 224, the previously installed borehole casing 96,
13 and expandable casing 126 in its unexpanded form that is
14 attached to the casing hanger at casing hanger end 222.
15 These elements have been previously defined in Figure 6 and
16 in Figure 7. Figure 12 shows the casing hanger after a
17 portion of it has been expanded with the casing hanger
18 setting tool. The state of the casing hanger 130 in Figure
19 12 is similar to that shown in Figure 10. The inside
20 diameter of the previously installed borehole casing 96 is
21 shown in Figure 12 by the legend ID2. The wall thickness of
22 the previously installed borehole casing is identified by the
23 legend WT2. The inside diameter of the expandable casing 126
24 in its unexpanded form is identified by the legend ID3. The
25 wall thickness of the previously installed borehole casing is
26 identified by the legend WT3. This is the configuration
27 before the passage of the subterranean liner expansion tool.
28

29 **Figure 13** provides a section view of the configuration
30 of components shown in Figure 12 after the passage by the
31 subterranean liner expansion tool. Various elements on
32 Figure 13 have been previously described. In addition,
33 element 358 shows the expandable casing in its expanded state
34 after the passage of the subterranean liner expansion tool.

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1 Various inside diameters are defined by legends ID2, ID4, and
2 ID5. In general, ID2 will equal ID4 that will equal ID5. If
3 this is the case, this is a true monobore well. However,
4 there are limitations to the power of the subterranean liner
5 expansion tool. So, if old hard cement is set up behind the
6 overlapping portions of the previously installed casing in
7 the location identified by element 360, the subterranean
8 liner expansion tool may not have sufficient power to crush
9 old hard cement and rock behind that particular location.
10 Such a location is identified by element 345 in
11 Figure 10. In such event, ID4 would be less than ID2 by as
12 much as 2 times the dimension of WT2 in Figure 12. This
13 extra thickness may persist for the length of the casing
14 hanger L1 as shown in Figure 7. Therefore, the installation
15 described in Figure 13 will provide either a monobore well,
16 or a near-monobore well.

17
18 In the following, there are different topics of interest
19 related to the above described preferred embodiment.
20 Subsection titles will be used for the purposes of clarity.
21

22 **Figure 14** shows relevant parameters related to fluid
23 flow rates through the umbilical. Umbilical fluid flow rates
24 are sufficient to support drilling as shown in Figure 9. One
25 preferred embodiment uses a 4.5 inch ID pipe providing 173
26 gallons per minute (GPM) at a pressure of 1000 pounds per
27 square inch (PSI) pressure loss over a 20 mile offset. Here,
28 the "Pressure Loss" is 1000 PSI. Here, the "Flow Rate" is
29 173 gallons per minute. This was calculated using a Bingham
30 Plastic mudflow model with 12 lb/gallon mud at a velocity of
31 3.5 feet per second (fps). This is a "Flow Velocity" of 3.5
32 feet per second. The umbilical geometry of 4.5 inches ID and
33 6.0 inches OD may be optimized under different situations as
34 required. However, these particular dimensions are selected

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1 for a reverse flow mud system inside a 8.5 inch ID cased hole
2 having a 20-mile offset. The Bingham Plastic mudflow model
3 is described in detail in Section 8.2 entitled "Mathematical
4 and Physical Models" of the book entitled "Petroleum Well
5 Construction" by Michael J. Economides, Larry T. Watters, and
6 Shari Dunn-Norman, John Wiley & Sons, New York, New York,
7 1998, an entire copy of which is incorporated herein by
8 reference. An entire copy of the book referenced in the
9 previous sentence is also incorporated herein by reference.
10 In particular, please refer to Table 8-2 on page 222 of the
11 book for detailed algebraic equations related to the Bingham
12 Plastic Model.

Tripping into the Well

There are various constraints on how rapidly the subterranean electric drilling machine can enter the wellbore. Since the vertically suspended casing string and the subterranean electric drilling machine weight may be greater than can be safely run with the umbilical, the first anchor and weight on bit mechanism (AWOBM) 140 and second anchor and weight on bit mechanism (AWOBM) 142 as shown in Figure 6 provide an anchor mechanism that acts as a "downhole hoist" to "walk" the casing vertically downhole and eventually into any horizontal section of the well. This "downhole hoist" is also called herein an "anchor mechanism" when used for this particular purpose. The subterranean electric drilling machine and its related anchor mechanism can be fielded from within a lubricator as is standard practice in the industry to maintain well pressure control. Once the downhole weight is within the capacity of the umbilical, use of the anchor mechanism is stopped and the casing load is transferred to the umbilical. The anchor means 144 and 146 and anchor means 148 and 150 as shown in

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Figure 6 of the anchor mechanism are then collapsed for rapid transit to the bottom of the well. Further downhole travel of the casing and the subterranean electric drilling machine is accomplished by pumping mud into the annulus space between the well's installed casing and the umbilical. Pressure acting upon this annular piston area generates sufficient force to rapidly move the equipment downhole at about 2 fps in the 15 to 20 mile offset range. A 225,000 lb load with a 0.2 coefficient of friction requires approximately 1,600 psi differential pressure across Smart Shuttle seals (see element 210 in Figure 6). This pressure capability is obtained with multiple seals load-sharing the pressure. Motion cannot be accomplished without moving mud from below the drilling machine out of the well up through the umbilical ID. The pressure in the casing below the drilling machine (a sealed volume due to cementing) is approximately 3500 psi above static. The downhole mud pump may be used to assist in moving this required mudflow through the umbilical ID. For trip velocities in the range of 2 feet per second the surface mud pumps will need to provide 350 gallons per minute at 4600 pounds per square inch. At shorter distances with less pressure losses, the equipment may move faster (if surface mud pump volume capacity is available).

25 Figure 15 shows various parameters related to tripping
26 the subterranean electric drilling machine and the expandable
27 casing into the well. A 20 mile well is on the order of
28 100,000 feet. At this distance, and at 2 feet per second,
29 the formation back pressure is 1000 PSI.

Tripping Out of the Well

33 The subterranean electric drilling machine 94 is tripped
34 from the well with cuttings filled mud within the umbilical.

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1 Sufficient mudflow is pumped down the annulus between the
2 umbilical and the uphole casing to fill the entire cased
3 wellbore below the drilling machine. The maximum pressure
4 the pump will provide this annulus is 5000 psi and at a
5 20 mile offset, the volume is limited to approximately 440
6 gallons per minute or a drilling machine trip speed of
7 approximately 2.4 fps. Simultaneously, the surface linear
8 umbilical traction unit pulls at approximately 12,500 lbs
9 (to overcome the fluid flow drag upon the umbilical, the
10 frictional umbilical drag and the frictional drag of the
11 subterranean electric drilling machine and its seals).

12

13 As the subterranean electric drilling machine moves up
14 the wellbore and the annular fluid pressure losses become
15 less, the maximum mud pump pressure no longer limits the trip
16 speed. The limiting factor then becomes the mud volumes,
17 which the mud pumps may provide. For these tripping
18 purposes, a third surface mud pump may be used in another
19 preferred embodiment. It will support higher speed trips and
20 provide redundancies during other operations.

21

22 Since all of the mud volumes pass through the downhole
23 mud pump, an accurate metering of the mud volume and
24 pressures is obtained throughout the trip. This keeps
25 pressure off the open formation during trips out of the
26 wellbore.

27

28 Surface Mud System

29

30 A large volume of working mud is needed to manage the
31 umbilical volume while tripping in the hole. For 20-mile
32 offset operations, an active mud tank volume of 3500 barrels
33 may be required. This is similar in capacity to those used
34 in some large offshore drilling rigs.

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In one preferred embodiment, the installed casing is 8.5 inches ID, and the umbilical is a 6 inch OD umbilical with a 4.5 inch ID. During drilling operations, the maximum mud flow rate is 150 gallons per minute with a pressure drop of 825 pounds per square inch, which includes frictional losses only. During tripping out of the hole at 2.4 feet per second, the maximum mud flow rate is 422 gallons per minute with a pressure drop of 4,750 pounds per square inch. During running in the hole with casing at 2 feet per second, the maximum mud flow rate is 350 gallons per minute, with a pressure drop of 3600 pounds per square inch (with cement sealed on the bottom of the well).

13

14 Thus, for the tripping out of the well, a minimum of
15 two 750 hp surface mud pumps would be required. One pump is
16 adequate for routine drilling operations. When the
17 subterranean electric drilling machine is at a distance of
18 20 miles, approximately 14 hours are required to run into the
19 hole, 12 hours are required to come out of the hole, and 11
20 hours are required for cuttings to circulate from the bottom
21 of the hole to the surface. Therefore, accurate monitoring
22 and management of mudflow and quality into and out of the
23 well and umbilical both at the surface and downhole at the
24 drilling machine is important for reliable well control.

25

The Drilling Operation

27

When the subterranean drilling rig reaches the bottom of the hole, the high-speed bit may encounter cement within the bore of the cased hole. The anchor means 144, 146, 148 and 150 as shown in Figure 6 are engaged, mud circulation started and the bit is rotated. Notice that downhole sensors monitor mudflow composition parameters to minimize circulation time for conditioning the hole. Weight on bit is applied and

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1 drilling moves forward out of the previously cased hole.
2 Traditional steering mechanisms and MWD tools are used to
3 guide forward progress of the bit through the formation.
4 Directly behind this BHA is the unexpanded casing.

5
6 The mudflow rates and the cutting solids this flow rate
7 can transport out of the hole will limit drilling progress.
8 For example, a drilled 12 1/2 inch ID hole and a 4 1/2 inch
9 ID umbilical having an internal mud velocity of 3 feet per
10 second carrying 6.5% solids will have a maximum penetration
11 rate of 90 ft/hr.

12
13 Significant information will be monitored and
14 communicated real time to the surface for control of the
15 operations. Some of the information includes:

- 16 (a) Weight on bit
17 (b) Penetration rate
18 (c) Bit RPM
19 (d) Bit power (determined from power consumed by the downhole
20 electric motor 114 of the subterranean drilling machine)
21 (e) Mud flow rate through bit (by monitoring throughput of
22 the progressing cavity pump 180)
23 (f) Differential mud pressures across bit and to surface
24 across umbilical
25 (g) Mud quality sensors for entrained gas, cuttings loading,
26 etc.
27 (h) Mud temperatures
28 (i) Basic operating parameters of the various subterranean
29 electric drilling machine functions that include voltage,
30 power, RPM, pressure, temperature, axial load in umbilical at
31 the pump, etc. are all monitored in real time to verify
32 equipment status.

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1 This monitoring will provide for efficient control of
2 the downhole drilling operation. If additional information
3 is required, in one preferred embodiment additional
4 instrumentation or tools may be included in the umbilical at
5 the various connection points (approximately every 5 miles).
6 In one preferred embodiment, it is preferable to have
7 remotely operated downhole BOP's. These devices are
8 packer-like assemblies, which when inflated, anchor to the
9 inside of the casing. An internal valve provides a well
10 fluid isolation point.

11
12 This extensive monitoring capability allows drilling
13 operations to use under-balanced fluids, if beneficial to the
14 well program. This equipment capability also allows for
15 direct well control and production testing through the
16 drilling machine.

17
18 When the well has drilled forward to the casing point,
19 pressuring the setting tool included in the subterranean
20 electric drilling machine sets the expandable casing hanger.
21 The success of the hanger setting operation may be load
22 tested with the downhole hoist (which when used in this
23 application is also called a "weight on bit mechanism").
24 Upon verification of a successful operation, the subterranean
25 electric drilling machine releases from the casing and starts
26 its trip from the well. This will leave the well ready for
27 casing cementing and casing expansion.

28
29 During all operations in a wellbore, the umbilical is
30 maintained under tension between the downhole tools and the
31 surface equipment. This permits rapid transit in the
32 wellbore by preventing buckling. A constraint is that a
33 minimum number of gentle bends should be included in the
34 wellbore design. This constraint is similar to familiar

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1 drill pipe and coiled tubing operational constraints in
2 current well operations. Selected means to provide such
3 tension are shown in Figure 5. The tension is monitored with
4 computer system 26 in Figure 5.

5

6 Several contingency operations are reviewed to
7 illustrate the capabilities of the subterranean electric
8 drilling system.

9

10 The subterranean electric drilling machine can control
11 the well and can control a well "kick", or well kicks.
12 In one preferred embodiment, the well uses a reverse
13 circulation system. The first mud cuttings and bypass port
14 (MCBP) 164 and the second mud cutting and bypass port 166 in
15 of the subterranean electric drilling machine act as a packer
16 within the well directing all returns to the umbilical. The
17 umbilical has sufficient pressure rating to contain any kick
18 and allow it to be circulated from the well. Instrumentation
19 monitoring mud conditions downhole should provide early
20 indication of developing well control problems.

21

22 The subterranean electric drilling machine can survive n
23 open hole collapse. The well is drilled with unexpanded
24 casing over the drilling work string (that is element 125 in
25 Figure 6). Should the formation collapse on the casing, the
26 subterranean electric drilling machine is withdrawn through
27 the unexpanded casing. The casing may subsequently be
28 expanded and drilling operations resumed.

29

30 The subterranean electric drilling machine can survive a
31 downhole blackout of power. Assume the failure is in the
32 power transmission or control system during a tripping
33 operation. The umbilical and surface traction winch
34 have sufficient power to pull the dead equipment from the

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wellbore. Surface pumps would continue to provide mud for displacement replacement. With care, mud pressure below the subterranean electric drilling machine may be used to reduce the load required to pull the machine from the well.

If the failure occurs when the drilling machine is anchored and making hole, then a release between the downhole mud pump and the anchor means of the drilling machine is actuated. That disconnect occurs between the female side of universal mud and electrical connector 176 and the male side of universal mud and electrical connector 178 as shown in Figure 6. In one preferred embodiment, the release may be triggered with an "over-pull" or operation may be via pumping a dart or ball down the umbilical. Once the release is actuated, the drilling machine controls, and mud pump assembly may be pulled "dead" from the well. Once the fault is isolated and repaired, the recovered equipment is run back into the well where it connects with the drilling equipment left in the hole. The Smart Shuttle portion of the subterranean electric drilling makes this reconnection. Regaining control of the equipment allows either drilling operations to proceed or for the equipment to be recovered from the well.

The Well Construction Process

Drilling and casing operations in the preferred embodiment is a two-trip process. The drilling equipment defined above (the subterranean electric drilling machine) is used to drill the hole, position and anchor the casing (but not expand it) within the hole. The casing is left in position ready for cementing operations (if required) and casing expansion to its final installed dimension is

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1 accomplished with the use of a second tool system (the
2 subterranean liner expansion tool).

3

4 In this preferred embodiment, the new expandable casing
5 is 3,000 feet long, 54 lbs/ft, and has an unexpanded OD of
6 8.0 inches OD. The downhole casing hanger and the casing
7 string are then suspended from the surface rig floor. The
8 bottom hole assembly (BHA) is then made up and run into the
9 casing string. In one preferred embodiment, the centralizing
10 casing hanger setting tool is used to lock the casing and
11 drilling equipment together. Next the rotary motor and the
12 anchor mechanism are added to the assembly together with the
13 downhole mud pump that may be used as a Smart Shuttle.

14

15 This described equipment is all long and heavy. It is
16 handled as major assemblies with quick connection devices
17 between each assembly. The estimated size and weight of
18 various components appear below in the following.

19

20 The bit is about 2 feet long, and weighs 500 lbs in air.
21 The MWD tools are 40 feet long and weigh about 1,200 lbs in
22 air. The rotary steering tool is about 30 feet long, and
23 weighs 1,500 lbs in air. The rotary shaft (element 125 in
24 Figure 6) also called the "drilling work string" or simply
25 "drill pipe", is about 3,000 feet long and weighs 28,500 lbs
26 in air. The expandable casing has a weight of 54 lbs/ft, is
27 about 3,000 feet long, and weighs 162,000 lbs in air. The
28 rotary section and anchor section of the subterranean
29 electric drilling machine (that includes elements 114, 140
30 and 142 in Figure 6) is about 120 feet long and weights
31 2,800 lbs. The downhole mud pump section of the subterranean
32 electric drilling machine (including elements 180, 196, and
33 214 in Figure 6) is about 122 feet long and weighs about
34 3,900 lbs in air. Any separate control module associated

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1 with the subterranean electric drilling machine is about 20
2 feet long and has a weight of 4,000 lbs. So, the total
3 length of the assembly is about 3,334 feet long that weighs
4 about 200,800 lbs in air.

5

6 Cementing and Expanding the Casing

7

8 In this preferred embodiment of the invention,
9 subterranean liner expansion tool 284 in Figure 10
10 installs the cement and expands the monobore casing in the
11 well. This approach was selected to simplify the
12 subterranean electric drilling machine and to provide
13 operational flexibility when performing these monobore well
14 construction operations.

15

16 The subterranean liner expansion tool has two basic
17 functions. The first is to cement the casing in the well
18 (if required). In one embodiment, this is accomplished
19 through a 2 inch cementing line in a 3 1/2 inch
20 OD umbilical. Unlike the subterranean electric drilling
21 machine when attached to casing, the Smart Shuttle at speeds
22 up to 10 feet per second pulls this umbilical into the well.
23 The Smart Shuttle operation of the liner expansion tool
24 requires that the inflatable cement seal 330 is collapsed,
25 and then fluids are pumped from the downhole side of the
26 Smart Shuttle™ seal 210 to the uphole side of that seal as
27 has been previously described. To cement the well,
28 inflatable cement seal 330 is inflated. This cement seal is
29 also called a straddle seal (with one side being inflatable)
30 on the tool's outside diameter that ensures the fluid
31 connection between the umbilical and the cement ports in the
32 casing hanger. Once the tool is in place, cement is
33 circulated into the annulus space behind the unexpanded
34 casing. Adequate instrumentation monitors cement placement,

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1 volume and Smart Shuttle location and reports all of these
2 monitored parameters to the surface.

3

4 The second function of the subterranean liner expansion
5 tool is to expand the casing to its final operating size.
6 The roller mechanisms for this task have already been
7 described in relation to Figure 10. Rollers provide power,
8 control and reversibility. If the casing were expanded with
9 internal pressure, it would lack any expansion control - for
10 example, if the hole diameter were irregular, then the casing
11 expansion would be irregular as well. Expansion dies have
12 the problem of being a one shot, one size expansion process.
13 Internal casing rollers have experience in buckled casing
14 repair tools and in anchoring casing inside Unibore
15 wellheads. Weatherford has developed a one step expansion
16 tool for expanding casing that is featured on their website.
17 Weatherford International, Inc. may be reached at 515 Post
18 Oak Blvd, Suite 600, Houston, Texas 77027, having the
19 telephone number of (713) 693-4000, that has the website
20 of www.weatherford.com. In Figure 10, the counter-rotating
21 roller casing expander tool 288 has contra-rotating rollers
22 to minimize the tool's torque that has to be externally
23 reacted while expanding the casing. The longitudinal rollers
24 318 and 320 in Figure 10 provide for this torque reaction.
25 As previously described, a downhole motor powered with a
26 separate electrical circuit from the surface provides the
27 necessary rotary power.

28

29 In a preferred embodiment, the surface equipment is
30 similar in arrangement to the drilling machine system.
31 However, this equipment may be smaller as the umbilical
32 OD may be chosen to be 3 1/2 inches OD.

33

34

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1 As described earlier, in one mode of operation of the
2 subterranean electric drilling machine, it acts like a Smart
3 Shuttle. The Smart Shuttle will be used to pump the
4 umbilical and the subterranean liner expansion tool to the
5 downhole worksite. The Smart Shuttle works by pumping fluid
6 from one side of the seals to the other with an electric
7 powered progressive cavity pump (PCP) (or any positive
8 displacement pump). At relative low differential pressures,
9 large axial forces (approximately 4,000 lbs net) are
10 generated that are sufficient to pull the tool and umbilical
11 into the hole. Top-hole speeds are the maximum design speed
12 of 10 fps. At extreme offsets, the speed will be slower (2.5
13 feet per second) due to fluid drag force on the umbilical,
14 which will be proportional to the transit speed.

15

16 The Smart Shuttle system is equipped with sensors to
17 detect location and to easily position the tools straddle
18 seals across the casing hanger of the last casing string.
19 Once in position, the inflatable seal is inflated and
20 circulation through the hole-casing annulus is confirmed.
21 This may be accomplished by pumping from the surface or by
22 using the Smart Shuttle pump to circulate the area. Cement
23 will be spotted into the annulus and the casing will be
24 expanded prior to the cement hardening.

25

26 Figure 10 illustrates the subterranean liner expansion
27 tool with cement being injected from the surface through the
28 umbilical. Approximately 69 gallons per minute will flow at
29 100,000 ft with a pressure loss of about 9,000 pounds per
30 square inch. Thus, the cementing pump will have to deliver
31 at 10,000 pounds per square inch at these rates. It will
32 require 240 minutes for the cement to be delivered at 100,000
33 ft from the surface and then another 77 minutes to spot
34 approximately 126 barrels of cement into the hole-casing

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1 annulus space. When operating at these large offsets,
2 managing the setting time of the cement and the required
3 volume of cement is important.

4

5 Tracers may be added to the fluid pads before and
6 following the cement as it is pumped into the umbilical.
7 Sensors located on the subterranean electric drilling machine
8 will verify when the cement is passing these downhole sensor
9 locations. This will help accurately spot cement into the
10 well. Once the cement is out of the umbilical, a bypass
11 valve is opened and mud is circulated through the annulus to
12 clear the umbilical.

13

14 Some casing may not require to be cemented into the
15 hole. It may be possible that the casing can be expanded
16 into the wall of the hole with sufficient pressure that the
17 residual contact stress between the rock and expanded casing
18 are sufficient to form an axial fluid seal. This avoids the
19 cementing step and simplifies operations. However, it places
20 a significant load upon the casing expansion rollers.

21

22 Once the cement is in position within the hole-casing
23 annulus, the inflatable cement seal 330 is deflated and the
24 Smart Shuttle pulls the expansion tool back into the
25 previously cased wellbore. The counter-rotating roller
26 casing expander tool is energized, and its roller engage the
27 casing ID by expanding until contact with the casing is
28 established. Rotation of the rollers is begun and the tool
29 slowly moves forward. Forward motion is provided by the
30 slight canted angle of the rollers, which screw the expander
31 into the casing hanger and pipe. This canted angle is shown
32 as the angle θ in Figure 10. In one preferred embodiment,
33 the counter-rotating roller casing expander tool has
34 sufficient strength to expand the casing hanger and the

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1 previously set casing back into the formation to provide a
2 smooth casing ID. This process is illustrated in Figures 12
3 and 13. Figure 12 shows the casing hanger area prior to
4 tool's passage and Figure 13 illustrates this same region
5 after the tool has passed. The subterranean liner expansion
6 tool has to have sufficient strength to expand the two casing
7 strings back into the formation rocks.

8

9 The subterranean liner expansion tool continues
10 expanding the casing to the bottom of the string. The
11 process of expanding the casing will reposition the cement
12 that is in the annuli. It will be extruded along the
13 reducing annuli until the cement reaches the end of the
14 casing where excess will flow into the uncased hole below the
15 expansion machine. Once the casing has been fully expanded,
16 the rollers of the subterranean liner expansion tool are
17 collapsed to their small transport size and the Smart Shuttle
18 and surface traction winch are used to bring the tool to the
19 surface. This leaves the hole ready for the next drilling
20 cycle.

21

22 Drilling and monobore casing operations continue until
23 the well reaches the target reservoir. It is then possible
24 to drill lateral drainholes (using a similar process) or a
25 single large bore completion may be made.

26

27 There are various methods to handle contingencies with
28 the subterranean liner expansion tool. Similar to the
29 subterranean electric drilling machine, considerable
30 flexibility exists in the cementing and expansion tool
31 concepts to handle most contingencies. A few of these
32 contingencies illustrate this capability.

33

34

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1 Suppose the power to the subterranean liner expansion
2 tool is cut off during a trip into the well.. A bypass valve
3 around the Smart Shuttle pump will open and allow the tool to
4 be pulled from the wellbore using the surface linear winch
5 and the strength of the umbilical. Alternatively, in some
6 wells, it may be possible to pump mud down the cement line in
7 the umbilical and apply pressure below the Smart Shuttle to
8 assist in its retrieval.

9
10 Suppose there is a loss of power with cement in the
11 umbilical. Then, a downhole bypass valve will open
12 connecting the umbilical bore with the cased well annulus.
13 Mud pumps may then be used to flow the cement to the surface.

14
15 Suppose the subterranean liner expansion tool fails
16 without expanding the entire casing string. The tool is then
17 recovered and the cement in the well annulus is assumed to
18 harden. The next drilling operation will be to mill out of
19 the wellbore and sidetrack to resume drilling to target.

20
21 Suppose the expansion strength of the subterranean liner
22 expansion tool is not sufficient to expand the casing hanger
23 to a full bore ID. The subterranean liner expansion tool has
24 the capability of operating at various diameters. It will
25 expand the casing to gage diameter where ever possible. Some
26 areas, (like the casing hanger area) may not achieve gage -
27 especially if the formation is exceptionally hard/strong.
28 The under gage diameter is not desirable, but not a
29 significant problem as all of the tool systems should pass
30 through this reduced diameter. Should it not be possible to
31 achieve the minimum gage diameter, then a mill may be used to
32 increase inside diameter as a last resort.

33
34

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Casing Flotation Techniques

Casing flotation techniques may be used to dramatically reduce the well annuli pressure required to pump casing into the well or reduce the required downhole hoist capacity. Air or nitrogen may be enclosed within the casing at the surface to reduce its apparent weight in mud during running operations. Once on bottom, the near buoyant casing would be flooded and filled with mud so that operations as previously described would continue. This and other related weight saving concepts have the potential to reduce the well annuli running pressure or downhole hoist capacity by 90% as compared to the loads identified above in the section entitled "The Well Construction Process". This capability allows much longer and/or heavier strings of casing to be optionally run.

Casing flotation techniques will not have an impact upon the umbilical's design criteria. The umbilical's internal working pressure defines its required axial strength. A 10,000 psi internal pressure for well control requires an umbilical axial load strength of approximately 160,000 lbs to resist the surface pressure effects.

Alternative Embodiments of Drilling Systems

In Figure 6, first anchor and weight on bit mechanism (AWOBM) 140 and second anchor and weight on bit mechanism (AWOBM) 142 are an example of "anchors" or "anchor means". In the following summary, the term "Anchor Means" may be capitalized.

In Figure 6, the expandable casing 126 is being "pushed" deeper into the wellbore by the anchor means. Therefore,

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1 this configuration is called a "Drill & Push" configuration.
2 In this situation, the anchor means are on the uphole side of
3 the subterranean electric drilling machine. On the other-
4 hand, if the anchor means were instead on the downhole side
5 of the subterranean electric drilling machine, then this
6 configuration would be called a "Drill & Drag" configuration.
7

8 In Figure 6, the anchor means are located on the inside
9 of the previously installed borehole casing 96. In this
10 configuration, the anchor means are located within the
11 "Wellbore". On the other-hand, if the anchor means are
12 instead located within the new borehole 104, then the anchor
13 means are located in the "Open-Hole".
14

15 In Figure 6, the downhole electric motor 114
16 rotates the rotary shaft 125 that is also called the
17 "drilling work string" or simply the "Drill Pipe".
18 In Figure 6, the downhole electric motor rotates the Drill
19 Pipe. Therefore, the "rotary means", in Figure 6 is
20 described by the following: "Rotates Drill Pipe". In
21 Figure 6, the expandable pipe 126 is not rotated. However,
22 there are other configurations of the rotary means including:
23 "Rotates Drill Pipe and Casing", and "In Open Hole Rotates
24 Bit". In the below defined list of different preferred
25 embodiments, the term "rotary means" is capitalized as
26 "Rotary Means".
27

28 In Figure 6, the expandable casing 126 is not rotated.
29 Therefore, in this configuration, the expandable casing is
30 "Non-Rotating". In other preferred embodiments, the
31 expandable casing can be rotated by the rotary means. In
32 this configuration, the expandable pipe is "Rotated".
33
34

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1 In Figure 6, the progressing cavity pump 180 is driven
2 by a downhole pump motor assembly generally designated by
3 element 182 that comprises the mud pump, or "Mud Pump" in
4 Figure 6. In this preferred embodiment, the Mud Pump is
5 located within the Wellbore.

6
7 Accordingly, the preferred embodiment shown in Figure 6
8 can be described as follows (Preferred Embodiment "A"):

9 Arrangement: Drill & Push

10 Anchor Means: In Wellbore

11 Mud Pump: In Wellbore

12 Rotary Means: Rotates Drill Pipe

13 Expandable Casing: Non-Rotating

14 Comments: Preferred Embodiment shown in Figure 6.

15
16 Accordingly, another preferred embodiment of the
17 invention may be succinctly described as follows
18 (Preferred Embodiment "B"):

19 Arrangement: Drill & Push

20 Anchor Means: In Wellbore

21 Mud Pump: In Wellbore

22 Rotary Means: Rotates Drill Pipe and Expandable Casing

23 Expandable Casing: Rotating

24 Comments: This requires higher rotary torque than
25 Preferred Embodiment "A".

26
27 Accordingly, another preferred embodiment of the
28 invention may be succinctly described as follows
29 (Preferred Embodiment "C"):

30 Arrangement: Drill & Drag

31 Anchor Means: In Open Hole

32 Mud Pump: In Wellbore

33 Rotary Means: In Open Hole, Rotates Drill Bit

34 Expandable Casing: Non-Rotating, Drags Behind Anchor Means

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1 Comments: This requires stable formations for
2 Open Hole Anchor Means.
3

4 Accordingly, another preferred embodiment of the
5 invention may be succinctly described as follows (Preferred
6 Embodiment "D"):
7

8 Arrangement: "Drainhole Drilling"

9 Anchor Means: In Wellbore

10 Mud Pump: In Wellbore

11 Rotary Means: Rotates Drill Pipe

12 Expandable Casing: Non-Rotating

13 Comments: Similar to Preferred Embodiment "A", except
14 smaller diameters of expandable casing used.

15 In the above, Preferred Embodiment "C" is further
16 described in the following document: U.S. Disclosure
17 Document No. 494374 filed on May 26, 2001 that is entitled in
18 part "Continuous Casting Boring Machine", an entire copy of
19 which is incorporated herein by reference.

20 In the above, Preferred Embodiment "D" is further
21 described in the following document: U.S. Disclosure
22 Document No. 495112 filed on June 11, 2001 that is entitled
23 in part "Liner/Drainhole Drilling Machine", an entire copy of
24 which is incorporated herein by reference.

25 The subterranean electric drilling machine has been
26 illustrated performing hydrocarbon drilling applications.
27 However, there are other preferred embodiments of the
28 invention. The subterranean electric drilling machine has
29 the capability of performing directional drilling over large
30 distances both onshore and offshore. This includes drilling
31 pipelines under large and deep rivers, across large
32 topographical features like cliffs or subsea escarpments.

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1 Other applications for the subterranean electric drilling
2 machine include near surface drilling in urban areas for
3 installation or replacement of utilities like water lines,
4 gas mains, sewers, storm drains, underground power lines, and
5 communication lines, including broadband cables and fiber
6 optic cables. The selected drill bit would be sized for the
7 application. These preferred embodiments are not further
8 described herein in the interests of brevity.

9

10 **Figure 16** is similar to Figure 9, except here the well
11 is being drilled from an onshore wellsite. Subterranean
12 electric drilling machine 94 is disposed within a previously
13 installed borehole casing 362 that is surrounded by existing
14 downhole cement 364. The subterranean electric drilling
15 machine 94 was described in relation to Figure 6. The
16 subterranean electric drilling machine is in the process of
17 drilling a new borehole 366 into geological formation 368.
18 Expandable casing 370 is carried into the new borehole by the
19 subterranean electric drilling machine. Umbilical 372
20 connects the subterranean electric drilling machine to a
21 land-based drill center 374 that has the hoist, the computer
22 systems, the umbilical carousel, etc. Surface casing 376 is
23 surrounded by cement 378. The bottom of the surface casing
24 is connected to previously installed casing 362 by casing
25 string 380. The ocean 382 has ocean surface 384 and ocean
26 bottom 386. Here, the new borehole is being drilled beneath
27 the ocean from a land-based drill center. The land 388 joins
28 the ocean at a beach 390.

29

30 **Figure 17** is similar to Figure 9 and Figure 16, except
31 here the well is being drilled from a land based drill site.
32 Subterranean electric drilling machine 94 is disposed within
33 a previously installed borehole casing 392 that is surrounded
34 by existing downhole cement 394. The subterranean electric

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1 drilling machine 94 was described in relation to Figure 6.
2 The subterranean electric drilling machine is in the process
3 of drilling a new borehole 396 into geological formation 398.
4 Expandable casing 400 is carried into the new borehole by the
5 subterranean electric drilling machine. Umbilical 402
6 connects the subterranean electric drilling machine to the
7 land based drill site generally designated by element 404.
8 Shown figuratively are hoist 406; the umbilical carousel,
9 computers, etc. 408; and another section of umbilical 410.
10 Element 411 figuratively shows a lubricator. Surface casing
11 412 is surrounded by cement 414. The bottom of the surface
12 casing is connected to previously installed casing 392 by
13 casing string 416. The surface of the earth is identified by
14 element 418.

15

16 **Figure 18** shows a subterranean electric drilling machine
17 420 that is drilling an open borehole in the earth.
18 Element 420 is called an open hole subterranean electric
19 drilling machine. Electric motor 422 turns shaft 424 that
20 rotates the rotary drill bit 426 that drills borehole 428 in
21 geological formation 430. First anchor and weight on bit
22 mechanism (AWOBM) 432 is connected to second anchor and
23 weight on bit mechanism (AWOBM) 434 by extensible shaft 436,
24 which elements comprise an anchor mechanism. Shaft 438
25 connects the female side of universal mud and electrical
26 connector 440 to the male side of universal mud and
27 electrical connector 442. Progressing cavity pump 444 is
28 driven by its pump motor 446. Inflatable seal 448 surrounds
29 the progressing cavity pump that makes a positive seal
30 against the borehole wall of geological formation 449. The
31 progressing cavity pump has inlet 450 and outlet 452. The
32 inflatable seal 448 and the progressing cavity pump form a
33 Smart Shuttle that can be used to move the open hole
34 subterranean electric drilling machine shown in Figure 18 in

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1 and out of the hole. Centralizer 454 is attached to the
2 portions of the tool body having electronics 456 and
3 bidirectional communications 458 with the surface. Mud
4 carrying umbilical 460 is connected to the cable head 462
5 that provides electrical power and mud to the open hole
6 subterranean electric drilling machine. Mud from the surface
7 through the umbilical proceeds down the interior of various
8 elements of the drilling machine that are not shown for
9 simplicity, and then mud laden cuttings return to the surface
10 through the annulus 464 between the borehole wall and the
11 outside diameter of the umbilical. The arrows in
12 Figure 18 show the direction of mud flow. The inflatable
13 seal 448 surrounding the progressing cavity pump is partially
14 collapsed during actual drilling operations to allow the mud
15 to pass. The inflatable seal 448 is inflated when quickly
16 transporting the open hole subterranean electric drilling in
17 and out of the well. In view of the detailed description
18 provided in Figure 6 and elsewhere, and in view of the
19 description herein, it is now evident how the open hole
20 subterranean electric drilling machine functions.
21 Accordingly, no further detail will be presented here in the
22 interests of brevity.

23

24 Figure 19 shows another subterranean electric drilling
25 machine 466 that is drilling an open borehole in the earth.
26 Element 466 is another embodiment of an open hole
27 subterranean electric drilling machine called a "screw drive
28 subterranean electric drilling machine". Figure 19 is
29 similar to Figure 18. Elements 422, 424, 426, 432, 434, 436,
30 438, 440 and 442 have been defined in relation to
31 Figure 18.

32

33 The fundamental change in Figure 19 is that the form of
34 the Smart Shuttle shown in Figure 18 has been replaced by the

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1 screw translator device 468. Element 470 has an electric
2 motor 472 (not shown for simplicity), related electronics,
3 and bidirectional communications electronics. When electric
4 motor 472 rotates the screw blades 474, then friction against
5 the mud in the hole 476 causes the screw translation device
6 468 to translate within the hole (if the anchor means of
7 elements 432 and 434 are in their retracted positions).
8 Reversing the rotation of the screw blades reverses the
9 direction of translation within the borehole. The female
10 side of universal mud and electrical connector 478 is
11 attached to the male side of universal mud and electrical
12 connector 480, that is in turn connected to umbilical 482,
13 however, elements 480 and 482 are not shown in Figure 19 for
14 the purposes of simplicity. Centralizers 484 centralize
15 element 470 within the wellbore 486. The arrows show the
16 path of the mud flow during drilling operations. In view of
17 the previous disclosure, it is evident how the screw drive
18 subterranean electric drilling machine is used to drill the
19 new borehole 488 in the geological formation 490.

20

21 In another preferred embodiment in Figure 19, the
22 screw blades 474 have a variable pitch, where the distance
23 between successive blades is a smaller distance to the
24 right-hand side of Figure 19 than to the left-hand side of
25 Figure 19. In yet another preferred embodiment, the pitch
26 between the screw blades 474 is variable and controlled by
27 the surface computer system 26. Various embodiments of
28 the "screw drive subterranean electric drilling machine" are
29 further described in U.S. Disclosure Document No. 494374
30 filed on May 26, 2001, that is entitled in part "Continuous
31 Casting Boring Machine", an entire copy of which is
32 incorporated herein by reference.

33

34

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1 Figure 20 shows a cross section of another embodiment of
2 an umbilical used for subterranean electric drilling machines
3 and for open hole subterranean electric drilling machines. A
4 version of Figure 20 was originally filed in the U.S.P.T.O.
5 on the date of October 2, 2000 as a portion of U.S.
6 Disclosure Document 480550. Umbilical 492 contains at least
7 one insulated electrical conductor 494. Each such conductor
8 has electrical copper conductors 496 encapsulated by
9 electrical insulation 498. As shown in Figure 20, there are
10 a total of 8 such insulated electrical conductors. In one
11 embodiment, the insulated electrical conductors may be chosen
12 to be the same as shown in Figure 1. Also shown is high
13 speed bidirectional data communications means 500, which may
14 be a fiber optic cable or a coaxial cable. The insulated
15 electrical conductors and the high speed bidirectional data
16 communication means is encapsulated by first composite
17 material 502. Second composite material 504 surrounds first
18 composite material. As described above, the specific
19 gravities of composite materials 502 and 504 may be
20 engineered so that the umbilical 492 is substantially
21 neutrally buoyant in wellbore fluids.

22
23 In one preferred embodiment of the invention in
24 Figure 20, the second composite material 502 is chosen for
25 its good strength, durability against abrasion in the well,
26 and perhaps for its electrical insulation properties. In one
27 embodiment of Figure 20, the first composite material is
28 chosen so with a particular specific gravity such that the
29 overall umbilical is neutrally buoyant in typical well fluids
30 (in 12 lb per gallon mud, for example, or in salt water, as
31 another example). As previously discussed, syntactic foam
32 materials having silica microspheres as provided by the
33 Cumming Corporation (www.emersoncumming.com) for such
34 purposes. The details on pressure balanced silica

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1 microspheres in syntactic foam may be reviewed in
2 Attachment 28 to the Provisional Patent Application Number
3 60/384,964 filed on June 3, 2002 that is entitled "Umbilicals
4 for Well Conveyance Systems and Additional Smart Shuttles and
5 Related Drilling Systems", an entire copy of which is
6 incorporated herein by reference.

7
8 The interior 506 of the umbilical is used to provide
9 drilling fluids or cement downhole as required. Therefore,
10 different embodiments of umbilicals provide electric power
11 downhole, bidirectional communications, and provide the
12 ability to conduct fluids to and from the borehole, which are
13 neutrally buoyant in the fluids present. Umbilicals handling
14 well fluids are also useful with a number of well services
15 including the use with straddle packers, injection tools, oil
16 gas separators, flow line cleaning tools, valves, etc. In
17 another preferred embodiment, the interior 506 may be filled
18 with composite materials to provide extra strength for
19 certain applications that is also substantially neutrally
20 buoyant.

21
22 Figure 21 shows yet another neutrally buoyant composite
23 umbilical in 12 lb per gallon mud. Outer spoolable composite
24 tubing 508 has an OD shown by legend OD6, and has an ID shown
25 by legend ID6. In a preferred embodiment, OD6 is equal to
26 1.75 inches O.D., and ID6 is equal to 1.25 inches I.D. In
27 one preferred embodiment, the composite tubing is chosen to
28 have a specific gravity of 1.50.

29
30 Three each 0.355 inch O.D. insulated No. 4 AWG Wires
31 510, 512 and 514 are disposed within the I.D. of the
32 spoolable composite tubing. Optical fiber 516 is also
33 disposed within the spoolable composite tubing. The
34 remaining available volume within the spoolable composite 518

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1 is then filled with pressure balanced silica microspheres in
2 syntactic foam that has a specific gravity of 0.60. A
3 calculation shows that this umbilical in 12 lbs/gallon mud
4 weighs -50 lbs for every 1,000 feet. Assuming a coefficient
5 of friction of 0.2, at 20 miles the umbilical could pull back
6 with a frictional force of 1,056 lbs. So, this umbilical is
7 substantially neutrally buoyant (or simply "neutrally
8 buoyant" as defined below).

9
10 In Figure 21, the insulated wire is rated at 14,000
11 volts. This particular wire is Part Number FEP4FLEXSC
12 available through Allied Wire & Cable located in Bridgeport,
13 Pennsylvania. This wire was previously described in relation
14 to Figure 1. As is evident from the discussion involving
15 Figure 1, the three power conductors can provide 160
16 horsepower (119 kilowatts) at 20 miles to do work at that
17 distance. No fluids are conducted down the interior of this
18 umbilical generally designated by element 520 in
19 Figure 21. This umbilical is also useful for other
20 applications to be discussed later.

21
22 Selecting different specific gravities for the
23 pressure balanced silica microspheres in syntactic foam
24 that fills the volume within the spoolable composite 518
25 allows different preferred embodiments to be designed to be
26 neutrally buoyant within different well fluids having
27 different densities. As a practical matter, an umbilical
28 having a particular density will be used within a range of
29 acceptable densities of well fluids.

30
31 **Figure 22** is a schematic drawing that shows a ship
32 performing subsea well servicing. Ship 522 in ocean 524
33 possesses an umbilical carousel 526 having umbilical 528 that
34 proceeds through lubricator 530 that houses Smart Shuttle

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1 532. Subsea well 534 on the ocean bottom 535 has mating
2 equipment 536 that mates to mating equipment 538 of the
3 lubricator 530. The lubricator is guided into place by
4 remotely operated vehicle 540 obtaining its power and
5 communications from umbilical 542. The umbilical carousel
6 for umbilical 542 is not shown for simplicity.
7

8 Upon entering the subsea well, the Smart Shuttle is to
9 proceed through the base of the lubricator 544 and into the
10 wellbore below (not shown in Figure 22). There, the Smart
11 Shuttle is to perform a well workover that requires fluids to
12 be injected into formation such as acids. Umbilical 528 may
13 be selected to be a suitable umbilical including umbilical 2
14 in Figure 1, and umbilical 492 in Figure 20. Equipment
15 resembling what is shown in Figure 5 is on board the ship so
16 that a computer system can control the workover operations.
17

18 In this case, umbilical 542 need not provide fluids to
19 the remotely operated vehicle 540. Therefore, umbilical 542
20 may be chosen from umbilicals that includes umbilical 520 in
21 Figure 21. Equipment resembling what is shown in Figure 5 is
22 also onboard ship so that a computer system can control the
23 remotely operated vehicle 540. The upper end of umbilical
24 542 proceeding to its carousel is not shown on the left-hand
25 side of Figure 22 for simplicity. In this case, the
26 umbilical 542 is designed to have any desired buoyancy in sea
27 water, that specifically includes densities greater than sea
28 water, as is conventional in the industry. The apparatus and
29 methods to control the power and communications is similar to
30 that shown in Figures 2, 3, 4 and 5 and will not be repeated
31 here for the purpose of brevity. In one preferred
32 embodiment, over 60 kilowatts of power is provided by
33 umbilical 542 to remotely operated vehicle 540. This power
34 is provided to the load of the remotely operated vehicle,

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1 which in several preferred embodiments, is an electric motor
2 that drives a propeller that provides thrust for the remotely
3 operated vehicle. For simplicity, Figure 22 does not show a
4 free floating remotely operated vehicle (ROV) tethered to the
5 ship by a free floating umbilical.

6

7 **Figure 23** is a schematic drawing similar to Figure 22.
8 Figure 23 also shows a ship performing subsea well servicing.
9 Ship 546 in ocean 548 possesses a first umbilical carousel
10 550 (not shown in Figure 23 for simplicity) having umbilical
11 552 that proceeds through lubricator 554 that houses Smart
12 Shuttle 556. Subsea well 558 on the ocean bottom 560 has
13 mating equipment 562 that mates to mating equipment 564 of
14 the lubricator 554. The lubricator is guided into place by
15 first remotely operated vehicle 566 that obtains its power
16 and communications from umbilical 568 that is deployed from
17 second umbilical carousel 570 (not shown in Figure 23 for
18 simplicity). In this case, the umbilical 568 is designed to
19 have any desired buoyancy in sea water, that specifically
20 includes densities greater than sea water as is conventional
21 in the industry. The upper end of umbilical 568 proceeding
22 to carousel 570 near the top of the crane on the right-hand
23 side of Figure 23 is not shown for simplicity.

24

25 Upon entering the subsea well, the Smart Shuttle is to
26 proceed through the base of the lubricator 572 and into the
27 wellbore below (not shown in Figure 22). There, the Smart
28 Shuttle is to perform a well workover that does not
29 necessarily require fluids to be injected into formation.
30 Therefore, umbilical 552 may be selected to be a suitable
31 umbilical including umbilical 520 in Figure 21. Equipment
32 resembling what is shown in Figure 5 is on board the ship so
33 that a computer system can control the Smart Shuttle, and any
34

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1 equipment attached to the Smart Shuttle, during workover
2 operations.

3

4 In this case, umbilical 568 need not provide fluids to
5 first remotely operated vehicle 566. Therefore, umbilical
6 568 may be chosen from umbilicals that includes umbilical
7 520 in Figure 21. Equipment resembling what is shown in
8 Figure 5 is also onboard ship so that a computer system can
9 control first remotely operated vehicle 566. In this case,
10 the umbilical 568 is designed to have any desired buoyancy in
11 sea water, that specifically includes densities greater than
12 sea water as is conventional in the industry. The apparatus
13 and methods to control the power and communications to first
14 remotely operated vehicle are similar to that shown in
15 Figures 2, 3, 4 and 5 and will not be repeated here for the
16 purpose of brevity.

17

18 Figure 23 shows second remotely operated vehicle 574
19 that obtains its power and communications from umbilical 576
20 that is deployed from third umbilical carousel 578 (not shown
21 in Figure 23 for simplicity). Second remotely operated
22 vehicle 574 is to suitably attach to the subsea well 558 and
23 is to remove fluids from the wellbore. Therefore, umbilical
24 576 may be selected to be a suitable umbilical including
25 umbilical 2 in Figure 1 and umbilical 492 in Figure 20.
26 The upper end of umbilical 576 proceeding to carousel 578
27 near the top of the crane on the left-hand side of
28 Figure 23 is not shown for simplicity. Equipment resembling
29 what is shown in Figure 5 is on board the ship so that a
30 computer system can control the operation of second remotely
31 operated vehicle 574. In this case, the umbilical 576 is
32 designed to have any desired buoyancy in sea water, that
33 specifically includes densities greater than sea water as is
34 conventional in the industry. In one preferred embodiment,

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1 over 60 kilowatts of power is provided by umbilical 576 to
2 remotely operated vehicle 574. This power is provided to the
3 load of the remotely operated vehicle, which in several
4 preferred embodiments, is an electric motor that drives a
5 propeller that provides thrust for the remotely operated
6 vehicle. In other embodiments, this power is provided to an
7 electric motor that drives a downhole pump. For simplicity,
8 Figure 23 does not show a free floating remotely operated
9 vehicle (ROV) tethered to the ship by a free floating
10 umbilical.

11
12 In Figures 22 and 23, the feedback control of the
13 voltage, RPM, current, and other parameters of an electric
14 motor within an remotely operated vehicle is accomplished by
15 analogy to that disclosed in relation to the electric motor
16 of the subterranean electric drilling machine. In the
17 interests of brevity, this feedback control of remotely
18 operated vehicles will not be further discussed.

19
20 **Figure 24** shows one embodiment of the Smart Shuttle™
21 generally designated with the numeral 580 that is located
22 within a "pipe means" 582 that includes a casing, drill pipe,
23 tubing, etc. The Smart Shuttle is comprised of a progressive
24 cavity pump 584 that has a rotor 586 and stator 588 as is
25 typical of such pumps. The progressive cavity pump is
26 coupled to gear box 590 that is in turn coupled to the
27 electrical submersible motor 592, which in turn is connected
28 to electronics assembly 594 having any downhole computer, the
29 downhole sensors, and communications system, which in turn is
30 connected by the quick change collar 596 to the umbilical
31 head 598 that is connected the umbilical 600.

32
33 The lower wiper plug assembly 602 has sealing lobe 604
34 and this assembly is firmly attached to the body of the

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1 progressive cavity pump at the location shown in
2 Figure 24. Lower wiper plug assembly has lower bypass
3 passage 606 which has electrically operated valves 608 and
4 610. The upper wiper plug assembly 612 has sealing lobe 614
5 and this assembly is firmly attached to the sections of the
6 apparatus having the gear box and the electrical submersible
7 motor at the location shown in Figure 24. The upper wiper
8 assembly also has permanently open upper bypass port 616 in
9 the embodiment shown in Figure 24.

10
11 In terms of Figure 24, and when the electrical
12 submersible motor is suitably turning the rotor of the
13 progressive cavity pump (PCP), a volume of fluid ΔV_2 per unit
14 time in the wellbore is pumped into the lower side port 618
15 of the PCP and out of the upper side port 620 of the PCP.
16 With valves 608 and 610 closed, the fluid ΔV_2 is then forced
17 through the upper bypass port 616 into the portion of the
18 well above the upper surface of the upper wiper plug
19 assembly. In this manner, the Smart Shuttle is then forced
20 downward into the wellbore. The Retrieval Sub 620 is
21 attached to the body of the Smart Shuttle by quick change
22 collar 622 that in turn is connected to the lower body of the
23 progressive cavity pump. This, and related embodiments of
24 the Smart Shuttle is used to transport equipment attached to
25 the Retrieval Sub into wells and out of wells. The Smart
26 Shuttle is an example of a "well conveyance means", or
27 simply, a "conveyance means". Fluid conduction means 624 is
28 able to conduct any fluids available from umbilical 600
29 through the Retrieval Sub 620, although that fluid conduction
30 means 624 is not shown in Figure 24 for simplicity. Fluid
31 conduction means 624 is fabricated using tubing and
32 technology currently available in the oil and gas industry.

33
34

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1 **Figure 25** shows another well conveyance means.
2 Umbilical 626 possesses one or more electrical conductors.
3 In several preferred embodiments, umbilical 626 possesses one
4 or more high power electrical conductors. Umbilical head 628
5 connects the umbilical to tractor conveyor 630. The tractor
6 conveyor has at least one friction wheel 632 which engages
7 the interior of pipe 634. The tractor conveyor has four
8 friction wheels as shown in Figure 25. Quick change collar
9 assembly 635 connects the tractor conveyor to the Retrieval
10 Sub 636.

11

12 The tractor conveyor 630 with its Retrieval Sub 636
13 installed in Figure 25 is an example of a "tractor conveyance
14 means", a "tractor deployer", or a "downhole tractor
15 deployment device". Electrical energy delivered via the
16 umbilical to the tractor conveyor is used to drive electrical
17 motors and/or electro-hydraulic systems 637 to provide
18 rotational energy to the friction wheels (although the
19 details of element 637 are not shown in Figure 25 for
20 simplicity). That rotational energy causes the tractor
21 conveyor to move within the well.

22

23 The tractor conveyance means in Figure 25 provides
24 similar operational features as different embodiments
25 previously described heretofore as Smart Shuttles. Fluid
26 conduction means 638 is able to conduct any fluids available
27 from umbilical 626 through the Retrieval Sub 636, although
28 that fluid conduction means 638 is not shown in Figure 24 for
29 simplicity. Fluid conduction means 638 is fabricated using
30 tubing and technology currently available in the oil and gas
31 industry.

32

33 By analogy with the Smart Shuttle, one embodiment of
34 the tractor conveyance means may be used as a portion of an

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1 "automated well drilling and completion system". As
2 described herein, this automated system is called the
3 "tractor conveyance system" or the "automated tractor
4 conveyance system". The tractor conveyance means is
5 substantially under the control of a computer system that
6 executes a sequence of programmed steps that has at least one
7 computer system located on the surface of the earth and has
8 means to convey at least one completion device attached to
9 the Retrieval Sub into the wellbore under the automated
10 control of the computer system. The automated system has at
11 least one sensor means located within the tractor conveyance
12 means, has first communications means that provides commands
13 from the computer system to the tractor conveyance means, has
14 second communications means that provides information from
15 the sensor means to the computer system, where the execution
16 of the programmed steps of the computer system to control the
17 tractor conveyance means takes into account information
18 received from the sensor means to optimize the steps executed
19 by the computer system to drill and complete the well.
20

21 The Retrieval Sub can be attached to a number of the
22 devices shown in **Figure 26**. Those devices include any
23 commercial tool or device 640; any logging tool 642; any
24 torque reaction centralizer 644; any scraper 646; any
25 perforating tool 648; any flow meter 650; any Downhole Rig
26 with rotary bit 652; any Universal Completion Device™ 654;
27 any straddle packer 656; any injection tool 658; any oil/gas
28 separator 660; any flow line cleaning tool 662; any casing
29 expanding tool 664; any plug 666; any valve 668; and any
30 locking mechanism 670. These different tools are either
31 defined in applicant's applications or are tools used in the
32 oil and gas industry. The point is that any of these devices
33 can be attached to the Retrieval Sub of the Cased Hole Smart
34 Shuttle 672 or to the Retrieval Sub of the Open Hole Smart

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1 Shuttle 674. These devices may similarly be attached to the
2 Retrieval Sub of the tractor conveyance means. Each such
3 device in this paragraph may be called a "completion device"
4 and collectively, these may be referenced as "completion
5 devices".

6
7 These devices specified in the previous paragraph may be
8 used for a variety of different purposes in the oil and gas
9 industry. Many of those tools can be used to serve wells.
10 Please refer to **Figure 27** that shows a diagrammatic
11 representation of functions that may be performed with the
12 Smart Shuttle or the Well Locomotive. Figure 27 shows that
13 the Smart Shuttle or the Well Locomotive shown
14 diagrammatically as element 676 may be used for the purposes
15 of completion 678 (ie., to perform completion services
16 on a well); production & maintenance 680 (ie., to perform
17 production and maintenance services on a well); enhanced
18 recovery 682 (ie., to perform enhanced recovery services on a
19 well); and for drilling 684. Under completion functions, or
20 "completion services", the Smart Shuttle and Well Locomotive
21 may be used for the completion of extended reach lateral
22 wells 686; for logging and perforating 688; for stimulation
23 and fluid services 690; may be used to install the Universal
24 Completion Device™ 692; and may be used to install completion
25 hardware such as plugs, valves, gages, etc. 694. Under
26 production and maintenance functions, or "production and
27 maintenance services", the Smart Shuttle and Well Locomotive
28 may be used for flow assurance services 696; for maintenance
29 and repair 698; for workovers, that include logging,
30 perforating, etc., 700; and for reservoir monitoring and
31 control 702. Under enhanced recovery functions, or "enhanced
32 recovery services", the Smart Shuttle and Well Locomotive may
33 be used for recompletions, well extensions, and laterals 704;
34 to install downhole separators 706; to perform artificial

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1 lift 708; to facilitate downhole injection 710; and for fluid
2 services 712. Under drilling functions, or under "drilling
3 services", the Smart Shuttle and the Well Locomotive may be
4 used for casing drilling purposes 714; for liner drainhole
5 drilling purposes 716; for coiled tubing drilling 718; and
6 for extended reach lateral drilling 720. Extensive details
7 are provided in about each of these functions in the related
8 U.S. Disclosure Documents and in the related Provisional
9 Patent Applications cited above.

10
11 Any one or more of the functions provided in the
12 previous paragraph is called a "well service". Two or more
13 of such functions are called "well services". The execution
14 of the programmed steps of the automated computer system to
15 control the Smart Shuttle™, or tractor conveyance means,
16 takes into account information received from the sensor means
17 within the tractor conveyance means to optimize the steps
18 executed by the computer system to service the well.
19

20 The above umbilicals have stated calculations pertaining
21 to lengths of 20 miles. However, the umbilicals can be any
22 length from 100's of feet to 20 miles. The extreme distance
23 of 20 miles was chosen to show neutrally buoyant umbilicals
24 can provide high power and high speed data communications at
25 great distances that has heretofore not been recognized in
26 the oil and gas industry.
27

28 As stated previously, the phrase "substantially
29 neutrally buoyant", "essentially neutrally buoyant", "near
30 neutral buoyant", and "approximately neutrally buoyant" may
31 be used interchangeably. In several preferred embodiments of
32 the invention, the meaning of these terms is that in the
33 presence of the well fluids, that the buoyancy of the
34

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1 umbilical causes the typical friction of the umbilical
2 against the well to be substantially reduced.

3

4 As stated earlier, the tractor conveyor tractor conveyor
5 630 with its Retrieval Sub 636 in Figure 25 is an example of
6 a "conveyance means", a "tractor conveyance means", a
7 "tractor deployer", or a "downhole tractor deployment
8 device". There are many "well tractors", or devices related
9 to well tractors, a selection of which are described in the
10 following documents: U.S. Patent Nos. 6,347,674; 6,345,669;
11 6,318,470; 6,296,066; 6,273,189; 6,257,332; 6,241,031;
12 6,241,028; 6,225,719; 6,179,058; 6,179,055; 6,173,787;
13 6,089,323; 6,082,461; 5,954,131; 5,794,703; 5,547,314;
14 5,375,668; 5,209,304; 5,184,676; 5,121,694; 5,018,451;
15 5,040,619; 4,960,173; 4,686,653; 4,643,377; 4,624,306;
16 4,570,709; 4,463,814; 4,243,099; 4,192,380; 4,085,808;
17 4,071,086; 4,031,750; 3,969,950; 3,890,905; 3,888,319;
18 3,827,512; in EP0564500B1; and in WO9806927; WO9521987;
19 WO9318277; and WO9116520; entire copies of which are
20 incorporated herein by reference. Entire copies of the 39
21 cited references in this paragraph are incorporated herein by
22 reference. Many of these devices are means to cause or
23 generate movement within wellbores. Such "movement means"
24 may be attached to a device similar to the Retrieval Sub 636.
25 Devices similar to Retrieval Sub 636 are called "retrieval
26 means". So, movement means may be coupled to retrieval means
27 to make a "tractor conveyance means", or tractor deployers,
28 or downhole tractor deployment devices.

29

30 In view of the above, several embodiments of this
31 invention use a closed-loop system to service a well for
32 producing hydrocarbons from a borehole in the earth having at
33 least one computer system located on the surface of the
34 earth, which possess at least one conveyance means to convey

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1 at least one completion device into the borehole under the
2 automated control of the computer system that executes a
3 series of programmed steps, which possess at least one sensor
4 means located within the conveyance means, which have first
5 communications means that provides commands from the
6 computer system to the conveyance means and possessing second
7 communications means that provides information from the
8 sensor means to the computer system, whereby the execution of
9 the programmed steps by the computer system to control the
10 conveyance means takes into account information received from
11 the sensor means to optimize the steps executed by the
12 computer to service the well. Such system is called a
13 "closed-loop tractor conveyance system". The closed-loop
14 system may also be used to monitor and control production of
15 hydrocarbons from the wellbore.

16

17 The above described umbilicals, and other variations of
18 such umbilicals that meet the above defined operational
19 specifications, could be manufactured on a contractual basis
20 by a firm called ABB Offshore Systems that is located in
21 Stavanger, Norway, that has its U.S.A. office that may be
22 reached through ABB Offshore Systems, Inc., having the
23 address of 8909 Jackrabbit Road, Houston, Texas 77095, having
24 the telephone number of (281) 855-3200, that has its website
25 that can be reached through www.abb.com. The above described
26 umbilicals, and other variations of such umbilicals that meet
27 the above defined operational specifications, might be
28 manufactured on a contractual basis by a firm called the
29 Fiberspar Corporation that may be reached at 28 Patterson
30 Brook Road, West Wareham, Massachusetts 02576, having the
31 telephone number (508) 291-9000, which has its website at
32 www.fiberspar.com. This firm is capable of supplying various
33 spoolable composite tubes capable of being spooled onto a
34 reel having relevant anisotropic characteristic, a specified

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1 burst pressure, a specified collapse pressure, a specified
2 tensile strength, a specified compression strength, a
3 specified load carrying capacity, which is also bendable.
4 Some of these tubes include an inner liner material, an
5 interface layer, fiber composite layers, a pressure barrier
6 layer, and an outer protective layer. The fiber composite
7 layers can have triaxial braid structure. The composites
8 may be fabricated from carbon-based composites.

9
10 In the above, syntactic foam materials were described in
11 various preferred embodiments to change the apparent buoyancy
12 of an umbilical in the presence of other surrounding fluids.
13 However, any material of a different density may be used for
14 this purpose.

15
16 A preferred embodiment above has described an apparatus
17 to drill oil and gas wells having subterranean electric
18 drilling machine disposed in a wellbore such as that shown
19 as element 94 Figure 6. The subterranean electric drilling
20 machine possesses at least one downhole electric motor that
21 is shown as element 114 in Figure 6. This electric motor
22 rotates a rotary drill bit identified as elements 106, 110
23 and 112 in Figure 6. This electric motor rotates the drill
24 bit at a selected RPM determined by the frequency, current
25 and voltage applied to input terminals of the electric motor
26 as shown in Figure 2 and in Figure 3. One advantage of such
27 an electrically operated drill bit operating at relatively
28 high RPM is that it produces very fine rock cuttings that are
29 easily transported to the surface by mud flow. The input
30 terminals of the electric motor are identified as the inputs
31 to the downhole electrical load 22 in Figure 2, which in
32 several embodiments is an electric motor, which are also
33 attached to the sensing unit 24. The input terminals of the
34 electric motor are shown a the leads attached to either side

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1 of element 34 in Figure 2. The electric motor operates
2 properly with a particular voltage level applied to its
3 electrical input. Please refer to the preferred embodiment
4 discussed in relation to electric motor 34 in Figure 3. It
5 is important to note that in several preferred embodiments,
6 the electrical motor 34 in Figure 3 is dissipating 160
7 horsepower (119 kilowatts). A surface power supply means
8 located on the surface of the earth provides a voltage output
9 that is identified with element 20 in Figure 2. An umbilical
10 means disposed in the wellbore surrounded by well fluids
11 connecting the surface power supply means to the subterranean
12 electric drilling machine provides electrical power to the
13 electrical input of the electric motor. For example, such an
14 umbilical means is shown as element 116 in Figure 6 and in
15 Figure 9. The umbilical means possesses insulated electric
16 wires as shown in Figures 1, and 20. The umbilical means
17 possess high speed data communications means such as high
18 speed data link 14 in Figure 1. The umbilical means
19 possesses a fluid conduit for conveying drilling fluids
20 through the interior of the umbilical means such as element 8
21 in Figure 1 and 506 in Figure 20. The preferred embodiment
22 has means to measure first voltage applied to the first
23 electrical input of the electrical motor as shown by element
24 in Figure 2. The preferred embodiment possesses means to
25 transmit information related to the measured first voltage
26 through a high speed data communications means within the
27 umbilical to a computer located on the surface of the earth
28 by using the high speed data link 14 in Figure 1. The
29 embodiment further possesses computer controlled means to
30 adjust the first voltage output as shown by element 28 in
31 Figure 2. The computer system 26 in Figure 2 is used to
32 maintain first voltage input at a particular voltage level to
33 provide proper operation of the electric motor within the
34 subterranean electric drilling machine.

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1 In several preferred embodiments, the electric
2 motor 34 in Figure 3 dissipates in excess of 60 kilowatts.
3 This is important because it is the recollection of the
4 inventors that several scientists and senior managers of a
5 major oil services company stated their opinions that it
6 would be impossible to provide over 60 kilowatts to an
7 electric motor, or any other electrical load, at distances of
8 up to 20 miles from a wellsite through any type of reasonably
9 sized umbilical that would be practical to use within
10 wellbores. According to the recollection of the inventors,
11 these senior managers and scientists clearly stated their
12 opinions before the invention herein was disclosed to those
13 particular individuals. Yet further from this recollection,
14 it apparently never occurred to these same scientists and
15 senior managers that any such umbilical delivering in excess
16 of 60 kilowatts could also be neutrally buoyant. However,
17 only after disclosure of the invention herein to those
18 scientists and senior managers, did they apparently accept
19 that such umbilicals could be designed and built.
20 Accordingly, because the individuals involved are well known
21 in the oil and gas industry, and are experts in fields
22 directly pertaining to the invention, the preferred
23 embodiment described herein is not obvious to one having
24 ordinary skill in the art.

25
26 Therefore, a preferred embodiment is an apparatus to
27 drill oil and gas wells comprising:

28
29 (a) a subterranean electric drilling machine disposed in a
30 wellbore that possesses at least one electric motor that
31 rotates a rotary drill bit at a selected RPM, whereby the
32 electric motor possesses first electrical input, whereby the
33 electric motor properly operates with a particular voltage
34 level applied to first electrical input, and whereby the

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1 electric motor dissipates in excess of 60 kilowatts with the
2 particular voltage level applied to the first electrical
3 input;

4

5 (b) surface power supply means located on the surface of the
6 earth providing first voltage output;

7

8 (c) umbilical means disposed in the wellbore surrounded by
9 well fluids connecting the surface power supply means to the
10 subterranean electric drilling machine that provides
11 electrical power to the first electrical input of the
12 electric motor, whereby the umbilical means possesses
13 insulated electric wires, whereby the umbilical means
14 possesses high speed data communications means, and whereby
15 the umbilical possesses a fluid conduit for conveying
16 drilling fluids through the interior of the
17 umbilical means;

18

19 (d) means to measure first voltage applied to the first
20 electrical input of the electrical motor;

21

22 (e) means to transmit information related to the measured
23 first voltage through the high speed data communications
24 means within the umbilical to a computer located on the
25 surface of the earth;

26

27 (f) computer controlled means to adjust the first voltage
28 output so as to maintain first voltage input at the
29 particular voltage level to provide proper operation of the
30 electric motor within the subterranean electric drilling
31 machine.

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1 a approximately neutrally buoyant within the well fluids to
2 reduce the frictional drag on the neutrally buoyant
3 umbilical.

4

5 In view of the above disclosure, yet another preferred
6 embodiment is the method of feed-back control of an electric
7 motor having at least one voltage input located within a
8 subterranean electric drilling machine located in a borehole
9 that dissipates at least 60 kilowatts that receives power
10 from a surface power supply through an umbilical surrounded
11 by well fluids that possesses at least two insulated electric
12 wires, whereby the umbilical also possesses high speed data
13 link for data communications, comprising the steps of:

14

15 (a) measuring the voltage input to the electric motor;

16

17 (b) sending information related to the measured voltage input
18 through the high speed data link to a computer located on the
19 surface of the earth; and

20

21 (c) using the computer to adjust the voltage output of the
22 surface power supply that is used to control the voltage
23 input to the electrical motor.

24

25 Another preferred embodiment of the invention described
26 in the previous paragraph provides an umbilical that is
27 a approximately neutrally buoyant within the well fluids to
28 reduce the frictional drag on the umbilical.

29

30 In view of the above disclosure, yet another preferred
31 embodiment is the method of providing in excess of 60
32 kilowatts of electrical power to the electrical motor of a
33 subterranean electric drilling machine through a
34 substantially neutrally buoyant composite umbilical

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1 containing electrical conductors to reduce the frictional
2 drag on the neutrally buoyant umbilical.
3

4 In view of the disclosure related to Figures 22 and 23,
5 it is evident that the invention may be used to provide
6 electrical power to an electric motor located within a
7 remotely operated vehicle. Accordingly, a preferred
8 embodiment of the invention provides a method of feed-back
9 control of an electric motor having at least one voltage
10 input located within a remotely operated vehicle that
11 dissipates at least 60 kilowatts that receives power from a
12 power supply located on a ship through an umbilical
13 surrounded by sea water that possesses at least two insulated
14 electric wires, whereby the umbilical also possesses high
15 speed data link for data communications, comprising the
16 steps of:

17

18 (a) measuring the voltage input to the electric motor;

19

20 (b) sending information related to the measured voltage input
21 through the high speed data link to a computer located on the
22 ship; and

23

24 (c) using the computer to adjust the voltage output of the
25 power supply located on the ship that is used to control
26 the voltage input to the electrical motor.

27

28 Accordingly, yet another preferred embodiment of the
29 invention is the method of providing in excess of 60
30 kilowatts of electrical power to the electric motor of a
31 remotely operated vehicle through an umbilical containing
32 electrical conductors and at least one high speed data
33 communications means.

34

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1 Several of the above preferred embodiments describe
2 the Subterranean Electric Drilling Machine™, or simply the
3 Subterranean Drilling Machine™ (SDM™), that performs
4 Subterranean Electric Drilling™ (SED™) that is used to
5 construct a Subterranean Electric Drilled Monobore Well™
6 or an SED Monobore Well™. Several of the above preferred
7 embodiments also describe the Subterranean Liner Expansion
8 Tool™ (SLET™) otherwise called the Casing Expansion Tool™
9 (CET™).

10 Figure 28 shows a fixed platform 800 penetrating ocean
11 water 804 that is anchored in the ocean bottom at a
12 particular location 808. Production flowline 812 and
13 production flowline 816 carry oil and gas production to the
14 fixed platform. Steel cased well 820 penetrates the ocean
15 bottom at location 824 which is terminated in the first
16 subsea Xmas Tree 828. Oil and gas production flows from the
17 first Xmas Tree through jumper 832 to manifold 836. Oil and
18 gas production flows from manifold 836 through flowlines 812
19 and 816 to the TLP 800. Subsea control umbilical 840 is
20 connected to mid-flowline tie-in manifold 844 for a second
21 Xmas Tree that in turn is connected to subsea control
22 umbilical 848 that proceeds to the Umbilical Termination
23 Assembly ("UTA") 852. (The second Xmas Tree is not shown in
24 Figure 28 for the purposes of simplicity.) Control signals
25 are then sent through the Flying Leads, such as Flying Lead
26 856, that in turn are connected to the first Xmas Tree to
27 control well production. Mid-flowline tie-in manifold 844 is
28 connected to jumper 860 that is connected to assembly 864.
29 Oil and gas production also flows through flowline 868 to
30 assembly 864 and through flowline 872 to the TLP.

31 Installations such as shown in Figure 28 are typical in
32 the Gulf of Mexico. Figure 28 shows a typical satellite

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1 field system. In some cases, the flowlines are single steel
2 pipes, which are subject to wax build-up and to other
3 blockage problems such as hydrates, scales or other solids
4 forming from the production due to a loss in static pressure
5 or in temperature, or to any other process or mechanism.
6 In other cases, steel pipe-in-pipe systems with the outer
7 pipe being externally insulated and hot water circulated
8 through the annulus between the two pipes is used to heat the
9 flowlines to avoid wax build-up and other blockage problems.

10
11 In Figure 28, the "host" is illustrated as a fixed
12 platform. However, many other "hosts" are possible including
13 the following: an FPSO (a "Floating, Processing, Storage and
14 Offloading" facility); all types floating platforms; Tension
15 Leg Platforms ("TLP's"); SPARS; floating platforms with dry
16 tree risers including TLP's and SPARS; etc. Here a SPAR is a
17 floating moored structure for offshore drilling and/or
18 production operations, which is typically a deep draft
19 structure with very low motions due to the environment, and
20 is especially suited for deepwater, and often supports dry
21 surface trees. For the purposes of this invention, a
22 "host" may include any of the previously listed structures
23 associated with the formal definition of an "offshore
24 platform" as defined above in quotes.

25
26 **Figure 29** shows another "host" system. Figure 29 shows
27 Floating Production, Storage, and Offloading structure (FPSO)
28 876 loading crude through flexible line 880 to shuttle tanker
29 884 located on ocean surface 888. This is a typical FPSO
30 arrangement as used in offshore Brazil and West Africa.
31 Mooring component 892 is anchored to the sea bottom at
32 location 896. Mooring component 900 is anchored to sea
33 bottom at location 904. Subsea wellhead 908 at location 912
34 on the sea bottom passes crude production through flowline

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1 916 to the FPSO. Subsea wellhead 920 at location 924 on the
2 sea bottom passes crude production through flowline 928 to
3 the FPSO. Subsea wellhead 932 at location 936 on the sea
4 bottom passes crude production through flowline 940 to the
5 FPSO. Subsea wellhead 944 at location 948 on the sea bottom
6 passes crude production through flowline 952 to the FPSO.
7 Often, the flowlines are single pipes that are subject to
8 blockage from wax and other substances.

9
10 Another host is shown in **Figure 30**. Here floating
11 platform 956 is shown floating in ocean 960 having ocean
12 surface 964. Steel cased well 968 penetrates the sea bottom
13 972 at location 974, and is attached to wellhead 976. Steel
14 flowline 980 is attached to wellhead 976 and lies on sea
15 bottom 972 for a distance until it raises off the sea bottom
16 at position 984. The upper extremity of the flowline 988,
17 also known as a riser, is connected to the floating platform,
18 and the riser is suspended below the floating platform having
19 a minimum radius of curvature R at location 992 shown in
20 **Figure 30**.

21
22 The Electric Flowline Immersion Heater Assembly
23 ("EFIHA") is generally shown as element 996 in **Figure 30**.
24 The EFIHA shown in **Figure 30** possesses Electrically Heated
25 Composite Umbilical ("EHCU") 1000. The inside diameter of
26 the steel flowline 980 is shown by the legend ID(FL) in
27 **Figure 30**. The wall thickness of the steel flowline 980 is
28 WT(FL), which is not shown in **Figure 30** in the interests of
29 brevity. The outside diameter of the EHCU is shown by the
30 legend OD(IH) in **Figure 30**. The wall thickness of the EHCU
31 is WT(IH), which is not shown in **Figure 30** in the interests
32 of brevity. Hydraulic seal 1004 is attached to the outside
33 diameter of the EFIHA at location 1008. Hydraulic seal 1004
34 may be comprised of multiple individual hydraulic sealing

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1 elements 1012, 1016, 1020, and 1024, which four elements are
2 shown in Figure 30, but which are not so labeled in the
3 interests of simplicity.

4

5 Hydraulic pressure may be generated with hydraulic
6 equipment 1030 (not shown in the interests of simplicity in
7 Figure 30) located on the floating platform 956. This
8 hydraulic pressure may be applied to the annular space
9 defined by the difference between the inside diameter of the
10 flowline ID(FL) and the outside demeter of the EHCU that is
11 OD(IH) that is shown as region 1034 in Figure 30. The
12 hydraulic pressure applied in region 1034 in Figure 30 is
13 defined as P(EFIHA). This pressure acts on the hydraulic
14 seal 1004 that generates force F(EFIHA) which is applied to
15 the EFIHA that is provided by the following equation:

16

17

$$F(EFIHA) = \pi \{ [ID(FL)/2]^2 - [OD(IH)/2]^2 \} P(EFIHA)$$

21

22 Equation 2.
23

24 The force shown in Equation 2 is used to force the EFIHA
25 down into the steel flowline. In one preferred embodiment of
26 the invention, if wellhead 976 is set by control means 1038
27 so that no fluid may flow back into the well, then when the
28 EFIHA is forced downward into the well by hydraulic force
29 F(EFIHA), any displaced fluid in the sealed system flows up
30 the inside of the EFIHA through region 1042 within the EFIHA
31 and to the floating platform at location 1046. This is
32 called "backflow" within the EFIHA. So, in this case, the
33 displaced fluid flows up the interior of the F(EFIHA) to the
34 floating platform.

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1 The EFIHA also possesses additional centralizing and
2 hydraulic sealing elements 1048 and 1052. Instrumentation
3 assembly and control assembly 1056 provides measurements of
4 the ambient well conditions such as the pressure P(EFIHA),
5 temperature (EFIHA), the depth, etc. The force used to drive
6 the EFIHA into the well results in a downward velocity
7 V(EFIHA) that may be a function of time. This downward
8 velocity V(EFIHA) influences the pressure P(EFIHA). The
9 force F(EFIHA) is adjusted so that the pressure P(EFIHA) does
10 not exceed some predetermined maximum pressure P(EFIHA-MAX).
11 The Electrically Heated Composite Umbilical ("EHCU") 1000
12 possesses internal electric heater wires, wires to power the
13 instrumentation and control assembly 1056, means for high
14 speed bidirectional communications, and power wires for any
15 other services or purposes. As one example, wires 494 and
16 496 in the umbilical shown in Figure 20 may be used instead
17 as electrical resistors to generate heat to heat the EHCU.
18 In this case, the heat delivered to the EHCU is equal to the
19 following:

$$22 \quad H(\text{EHCU}) = [I(\text{EHCU})]^2 R(\text{EHCU})$$

24 Equation 3.

27 Here, $H(\text{EHCU})$ is the power in watts ("heat") delivered
28 to the EHCU, the symbol I is the time averaged electrical
29 current flowing through wires 494 and 496 in Figure 20, and
30 $R(\text{EHCU})$ is the combined series resistance of wires 494
31 and 496. The current I is caused to flow through the
32 resistors by a power supply that is not shown for simplicity.

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1 Instrumentation and control assembly 1056 may be used to
2 sense the depth of the EHCU and the distance between the end
3 of the EHCU and the wellhead shown by the legend Z(IH).
4 In one preferred embodiment of the invention, when Z(IH)
5 reaches a predetermined value, then at least one hydraulic
6 locking mechanism (not shown in Figure 30 for simplicity)
7 within instrumentation and control assembly 1056 may be used
8 to lock the EHCU into place within the well.

9
10 In one preferred embodiment of the invention, when it is
11 time to retrieve the EHCU, and with wellhead 976 is set by
12 control means 1038 so that no fluids may flow into the
13 wellhead, then pressuring up the interior of region 1042 will
14 apply pressure to the downhole side of seal 1004 and force
15 the EHCU towards the floating platform 956 and out of the
16 well. Suitable spooling and handling equipment for the EHCU
17 are provided on the floating platform 988 which are not shown
18 in Figure 30 in the interests of simplicity. In another
19 preferred embodiment, the EHCU is simply pulled out of the
20 well by the spooling and handling equipment.

21
22 In another preferred embodiment, and after the EFIHA is
23 locked in place within the well, a cross-over valve 1055 (not
24 shown in Figure 30 for simplicity) can be located at location
25 1058 which location is towards the floating platform from the
26 position of seal 1004. When production is allowed to flow to
27 the floating platform, this cross-over valve can be set to
28 any one of three states ("State 1", "State 2", and
29 "State 3"). In State 1, oil and gas production would proceed
30 through the interior of EHCU to the floating platform.
31 For example, in State 1, oil and gas production would flow
32 through region 1057 of the EHCU that is located towards the
33 floating platform from seal 1004. In State 2, oil and gas
34 production would flow through region 1058 located between the

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1 outside diameter of the EHCU and the inside diameter of the
2 flowline. State 2 has the advantage that all the heat
3 generated in the EHCU is transferred to the surrounding
4 production. In State 3, the oil and gas production would
5 flow through both regions 1057 and 1058 simultaneously.
6 There are many variations of the invention.

7

8 The next 12 paragraphs are paraphrased from page 66,
9 line 41, to page 68, line 38, of Serial No. 09/487,197, now
10 U.S. Patent 6,397,946 B1, that issued on June 4, 2003, having
11 the inventor of William Banning Vail III, that was
12 incorporated entirely by reference in co-pending
13 Serial No. 10/223,025, having the Filing Date of 8/15/2002,
14 that is entitled "High Power Umbilicals for Subterranean
15 Electric Drilling Machines and Remotely Operated Vehicles".
16 These 12 paraphrased paragraphs originally related to
17 Figure 23 in U.S. Patent 6,397,946, but now relate to
18 **Figure 31** herein. In Figure 23 in U.S. Patent 6,397,946 B1,
19 a coiled tubing was conveyed downhole. In Figure 31 herein,
20 an Electric Flowline Immersion Heater Assembly ("EFIHA")
21 having an electrically heated composite umbilical ("EHCU") is
22 conveyed into a flowline. In addition, an extra "0" was
23 added to all numerals that appeared in the corresponding text
24 of U.S. Patent No. 6,397,946 B1, so for example element 780
25 in Figure 23 in U.S. Patent No. 6,397,946 is now labeled as
26 element 7800 in Figure 31 herein.

27

28 However, the Smart Shuttles may be conveyed downhole
29 with an attached Electric Flowline Immersion Heater Assembly
30 ("EFIHA") having an electrically heated composite umbilical
31 ("EHCU") that is conveyed into a flowline. Such a Smart
32 Shuttle with Retrieval Sub that is conveyed downhole that is
33 attached to an EHCU is shown in Figure 31 herein. In several
34 preferred embodiments of the invention, the EHCU conveyed by

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1 the Smart Shuttle into the flowline as shown in Figure 31 may
2 be forced into the flowline by three different mechanisms:
3 (a) by using mechanical "injectors" at the surface to force
4 the coiled tubing downward into the flowline; (b) the PCP/ESM
5 assembly may be used to assist by "pulling" the Smart Shuttle
6 into the flowline; and (c) yet further, hydraulic forces on
7 fluids from the surface may also force the Smart Shuttle into
8 the flowline. That these three independent methods may be
9 used to force the Smart Shuttle with its attached Retrieval
10 Sub downward into the flowline will become better apparent
11 with the following description of the elements in Figure 31.
12

13 Most of the elements in Figure 31 through element 7200
14 have been previously described in relation to Figure 23 in
15 U.S. Patent 6,397,946 B1. The Progressive Cavity Pump is
16 labeled with element 6800. The Progressive Cavity Pump is
17 coupled to gear box 6830 that is in turn coupled to the
18 Electrically Submersible Motor 6840, which in turn is
19 connected to electronics assembly 6850 having any downhole
20 computer, sensors, and communications system, which in turn
21 is connected to the quick change collar 7700. The assembly
22 below the quick change collar in Figure 31 is often referred
23 to as the Progressive Cavity Pump/Electrical Submersible
24 Motor assembly that is abbreviated as the "PCP/ESM assembly".
25 Therefore, the "PCP/ESM assembly" is attached to the quick
26 change collar 7700 in Figure 31.

27
28 In Figure 31, an Electric Flowline Immersion Heater
29 Assembly ("EFIHA") that is generally shown as numeral 7722
30 has an Electrically Heated Composite Umbilical ("EHCU") 7724
31 that is conveyed into steel flowline 6782. Tubing
32 Termination Assembly 7780 has threads 7800 that mate to the
33 threaded end 7762 of EHCU 7724. So, the Tubing Termination
34 Assembly is inserted into the flowline and is attached to the

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1 threaded end 7762 of the EHCU 7724. In one preferred
2 embodiment, any fluids that flow into, or out of, the EHCU
3 are conducted to, and from, the interior of the flowline
4 through fluid channel 7820. Valve 7832 located within fluid
5 channel 7820 can be used to cut off any fluid flow through
6 the channel. Valve 7832 may be open or closed as desired.
7 For many of the following preferred embodiments, it is
8 assumed that this valve 7832 is open unless explicitly stated
9 otherwise. The wireline 7742 is connected to top submersible
10 plug 7840 that connects to lower submersible plug 7860 which
11 in turn passes the electrical conductors from the wireline to
12 the quick change collar. The bundle of electrical conductors
13 passing to the quick changer collar is designated with the
14 numeral 7880 in Figure 31. Within the quick change collar is
15 yet another electrical plug assembly that provides power and
16 electrical signals through a bundle of wires to the "PCP/ESM
17 assembly" that is not shown in Figure 31 solely for the
18 purposes of simplicity. Typical design and assembly
19 procedures used in the industry are assumed throughout this
20 specification. It is often the case that a quick change
21 collar surrounds male and female mating electrical
22 connectors, which is typically the case in "logging tools"
23 used in the wireline logging industry. Those connectors mate
24 at the location specified by the dashed line 7890 shown on
25 the interior of the quick change collar in Figure 31.

26

27 In addition, the Tubing Termination Assembly 7780 also
28 possesses expandable packer 7900. Upon command from the
29 surface, this expandable packer can be inflated within the
30 flowline to seal against the flowline as may be required
31 during typical well completion procedures, and typical
32 workover procedures, that are used in the industry. This
33 expandable packer can also be used for a second purpose of
34 forcing the Smart Shuttle into the wellbore as described

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1 below. This packer can also be used for additional purposes
2 as described below.

3
4 With reference to Figure 31, the Smart Shuttle may
5 be forced downhole by three mechanisms that are described
6 in separate paragraphs as follows.

7
8 In a first preferred embodiment of the invention,
9 mechanical "injectors" at the surface are used to force the
10 Electric Flowline Immersion Heater Assembly ("EFIHA") 7722
11 and its electrically heated composite umbilical ("EHCU") 7724
12 into the flowline 6782. These mechanical "injectors" were
13 previously described in U.S. Patent No. 6,397,946 B1, an
14 entire copy of which is incorporated herein by reference.

15
16 In a second preferred embodiment of the invention,
17 the electrically energized Progressive Cavity Pump forces
18 fluid ΔV_2 into the lower side port 7120 of the PCP and out of
19 the upper side port 7140 of the PCP, and the Smart Shuttle is
20 conveyed downhole. If this method is used by itself, and if
21 expandable packer 7900 is in its deflated state as shown by
22 the solid line in Figure 31, then no fluid would necessarily
23 flow to the surface through fluid channel 7820. It could,
24 but it is not necessary in this embodiment, and under the
25 circumstances described.

26
27 In a third preferred embodiment of the invention, and in
28 analogy with the pump-down single zone packer apparatus 658
29 described in Figure 17 in U.S. Patent No. 6,397,946 B1, the
30 expandable packer 7900 in Figure 31 is inflated so as to make
31 a reasonable seal against the flowline 6782, but not so
32 firmly so as to lock the device in place. In Figure 31, the
33 solid line labeled with numeral 7900 shows the uninflated
34 state of the expandable packer, and the dotted line shows the

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1 expanded, or inflated, state of expandable packer 7900.
2 Then, in analogy with fluid flow described in Figure 17 of
3 U.S. Patent No. 6,387,946 B1, fluid forced into the upper
4 flowline in annular region 7726 will force the apparatus
5 attached to the expandable packer downward into the wellbore,
6 and any fluid ΔV_3 displaced is forced upward through fluid
7 channel 7820 and into the interior of the EHCU 7728 which in
8 turn flows to the surface in analogy with previous
9 description of fluid flow through coiled tubing to the
10 surface in relation to Figure 17 in U.S. Patent 6,397,946.
11 This of course assumes that valve 7832 is open.

12
13 In principle, all first, second, and third methods of
14 conveyance downhole can be used simultaneously, provided that
15 valves 6980 and 7000 are set in their appropriate positions
16 for the applications, provided that valve 7832 is set in its
17 appropriate position, and provided the Progressive Cavity
18 Pump 6800 is suitably energized.

19
20 For simplicity, the particular embodiment of the
21 invention shown in Figure 31 will be called in certain
22 portions of the text that follows the "Electric Flowline
23 Immersion Heater Assembly with Wireline Smart Shuttle"
24 abbreviated "EFIHAWWSS" that is generally designated as
25 numeral 7922 in Figure 31.

26
27 Any smart completion device may be attached to the
28 Retrieval Sub 7180 during any such conveyance downhole. For
29 example, a casing saw or another packer can be installed on
30 the Retrieval Sub so that many different services can be
31 performed during one trip downhole. The casing saw and
32 packers are described in U.S. Patent No. 6,397,946 B1. These
33 include perforating, squeeze cementing, etc. - in fact many
34 of the methods to complete oil and gas wells defined in

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1 the book entitled "Well Completion Methods", "Well Servicing
2 and Workover", Lesson 4, from the series entitled "Lessons in
3 Well Servicing and Workover", Petroleum Extension Service,
4 The University of Texas at Austin, Austin, Texas, 1971, an
5 entire copy of which is incorporated herein by reference.
6

7 In another preferred embodiment of the invention, the
8 apparatus in Figure 31 may be used to test production, or to
9 assist production if it is used in another manner. In this
10 embodiment, an electrically actuated production flowline lock
11 7940 (not shown in Figure 31) is attached to the Retrieval
12 Sub 7180. It has passages through it so that hydrocarbons
13 below it can pass through it if necessary, but it otherwise
14 locks the apparatus in Figure 31 to the inside of the casing.
15 Once locked in place, the PCP/ESM assembly can pump
16 hydrocarbons through lower side port 7120 of the PCP and out
17 of the upper side port 7140 of the PCP. Thereafter,
18 hydrocarbons are pumped through fluid channel 7820 of the
19 Tubing Termination Assembly 7780 in Figure 31 provided that
20 the expandable packer 7900 is suitably inflated. There are
21 many variations on this particular embodiment of the
22 invention but they are not further described here solely in
23 the interests of brevity. With this embodiment, and with the
24 PCP forcing fluids up the inside of the EHCU, then this
25 provides a method of artificial lift for the produced
26 hydrocarbons.
27

28 Figure 31 also shows the Retrieval Sub electrical
29 connector 3130, the rotor 6810 of the Progressing Cavity
30 Pump, and the stator 6820 of the Progressing Cavity Pump.
31 The Retrieval Sub 7180 is attached to the body of the Smart
32 Shuttle by quick change collar 7200 that in turn is connected
33 to the lower body of the Progressive Cavity Pump.
34 The lower wiper plug assembly 6920 has sealing lobe 6940 and

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1 this assembly is firmly attached to the body of the
2 Progressive Cavity Pump at the location generally specified
3 by numeral 6960 and this assembly further has lower bypass
4 passage 6980 which has electrically operated valves 7000 and
5 7020. In Figure 31, the Smart Shuttle is comprised of the
6 Progressing Cavity Pump 6800 and the wiper plug assembly
7 6920.

8

9 Figure 31 may be used to illustrated yet other preferred
10 embodiments of the invention. The region of the well below
11 the lower wiper plug assembly 6920 is designated by element
12 6802. The annular region of the well between the lower wiper
13 plug assembly 6920 and the inflatable packer 7900 is
14 designated by element 6804. The annular region of the well
15 above the inflatable packer has already been designated by
16 numeral 7726. In another preferred embodiment of the
17 invention, the PCP may be used to pump fluids from region
18 6802 to region 6804. In this embodiment, valve 7832 is
19 closed and the inflatable packer 7900 is in its uninflated
20 state that is shown by the solid line in Figure 31. In this
21 embodiment, hydrocarbons produced from the well will be
22 pumped to the surface through region 7726 of the well. In
23 this case, the EHCU will heat the hydrocarbons to prevent any
24 build up of wax, hydrates, or other blockage substances in
25 the well. In yet another preferred embodiment of the
26 invention, valve 7830 may also be left open, and in such case
27 produced hydrocarbons would not only flow through region 7726
28 to the surface but also within the EHCU 7728 to the surface.

29

30 In Figure 32, all the elements have been described
31 except elements 7723, 7725, 7764, 7842, 7862, 7924, 8000, and
32 8010. In Figure 32, there is no wireline within the
33 Electrically Heated Composite Umbilical ("EHCU") 7725. In
34 Figure 32, an Electric Flowline Immersion Heater Assembly

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1 ("EFIHA") is generally shown as numeral 7723 having an
2 Electrically Heated Composite Umbilical ("EHCU") 7725 that is
3 conveyed into steel flowline 6782. Tubing Termination
4 Assembly 7780 has threads 7800 that mate to the threaded end
5 7764 of EHCU 7725. Element 7924 in Figure 32 generally
6 designates the Smart Shuttle Conveyed Electric Flowline
7 Immersion Heater Assembly ("SSCEFIHA") disposed within the
8 flowline 6782.

9
10 The EHCU 7725 possesses electrical heater wires, power
11 cables, any hydraulic tubes, fiber-optic cables, etc. within
12 the wall thickness of the EHCU. The wall thickness of the
13 EHCU is defined by the legend "WT(EHCU)", although that
14 legend is not shown in Figure 32 for the purposes of
15 simplicity. Assembly 8000 provides means to pass the heater
16 wires, power cables, any hydraulic cables, fiber-optic
17 cables, etc. from within the wall thickness of the EHCU to
18 jumper 8010 that connects to connector 7842 that in turn
19 mates to connector 7862.

20
21 In Figure 32, the Smart Shuttle is comprised of the
22 Progressing Cavity Pump 6800 and the wiper plug assembly
23 6920. In one mode of operation of a preferred embodiment,
24 fluid is pumped from the bottom side of the wiper plug
25 assembly to the top side of the wiper plug assembly, and with
26 expandable packer 7900 in the collapsed position shown in
27 Figure 32, the Smart Shuttle will convey the Electric
28 Flowline Immersion Heater Assembly ("EFIHA") 7723 down into
29 flowline 6782 (provided valve 7832 is open, and valves 6980
30 and 7000 are closed).

31
32 Figure 33 is similar to Figure 32, except here,
33 expandable packer 7900, is in its extended position and makes
34 contact with the interior wall of the flowline that is shown

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1 by the expanded solid line that is shaded. In this case,
2 fluid pressure P provided to annular region 7726 by pumps
3 located on the host (such as a floating platform), provide a
4 net downward force on the assembly shown in Figure 33. There
5 are several different modes of operation that amount to
6 different preferred embodiments of the invention.

7

8 In a first preferred embodiment, the Progressive Cavity
9 Pump is turned on, valves 6980 and 7000 are closed, and valve
10 7832 is open. Here, the volume pumped by the Progressive
11 Cavity Pump is ΔV_2 is equal to ΔV_3 . Further, the volume
12 pumped ΔV_3 is equal to the fluid displaced in the flowline
13 during the downward travel of the apparatus shown in
14 Figure 33. Therefore, if any portion of the flowline is open
15 to a reservoirs, or other source of fluid, below the
16 apparatus shown in Figure 33 (in region 6802), no fluid will
17 be forced into those reservoirs, or other sources of fluid
18 due to the downward motion of that apparatus. In another
19 embodiment of the invention, the volume pumped by the
20 Progressive Cavity Pump ΔV_2 is always equal to, or greater
21 than ΔV_3 . In yet another embodiment of the invention, the
22 volume pumped by the Progressive Cavity Pump is ΔV_2 is
23 substantially equal to ΔV_3 . Many other variants of this
24 preferred embodiment are possible. This particular method of
25 conveyance of coiled tubings into cased wellbores was
26 substantially described on page 67, lines 53-67, and on
27 page 68, lines 1-4, of U.S. Patent No. 6,387,946 B1.

28

29 In a second preferred embodiment, the Progressive Cavity
30 Pump is turned off, valves 6980, 7000, and 7832 are open, and
31 the pressure P forces Electric Flowline Immersion Heater
32 Assembly ("EFIHA") 7723 down into flowline 6782.

33

34

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1 **Figure 34** shows yet another preferred embodiment of the
2 invention that shows an Electric Flowline Immersion Heater
3 Assembly ("EFIHA") 7727 generally disposed in a flowline
4 6782. Element 6806 shows the annular portion of the wellbore
5 below the EFIHA, element 6808 shows the annular region of the
6 well above the Retrieval Sub 7180 and below the inflatable
7 packer 7900, and the region of the well above the inflatable
8 packer 7726 has been previously defined. The other numerals
9 have already been defined in Figure 34. Functionally, this
10 is very similar to the "second preferred embodiment"
11 described in the previous paragraph. The Smart Shuttle in
12 Figure 33 has been removed to make the apparatus in
13 Figure 34. In this embodiment, valve 7832 is open, and the
14 pressure P forces Electric Flowing Immersion Heater Assembly
15 ("EFIHA") 7727 into the flowline. This installs the
16 Electrically Heated Composite Umbilical ("EHCU") 7725 within
17 flowline 6782.

18

19 **Figure 35** shows cased well 1060 penetrating the sea
20 bottom 1064 at location 1068. Steel cased well 1060 is
21 attached to XMas Tree 1072 having control means 1076. The
22 XMas Tree 1072 is attached to steel flowline 1080 that lies
23 on the sea bottom until location 1084. At location 1084 the
24 flowline begins its ascent to the upper portion of the
25 flowline 1088, also known as a riser, that is connected to
26 floating platform 1092.

27

28 For the purposes of this invention, the term "Xmas
29 Tree", "subsea wellhead", and "wellhead" may be used
30 interchangeably.

31

32 **Figure 35** shows an Electrically Heated Composite
33 Umbilical ("EHCU") 1096 being installed within the flowline
34 1080 by tractor means 1100 having retractable traction wheels

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1 1104 and 1108, tractor body 1112, tractor locking mechanisms
2 1116 and 1120, cablehead 1124 obtaining electrical power and
3 control signals from wireline 1128 (which may also be an
4 umbilical). The cablehead provides electrical power and
5 control signals to the tractor body through connector 1132
6 which in turn provides electrical power and control signals
7 to run the electrical motors that energize the traction
8 wheels. The floating platform floats in ocean 1136 having
9 ocean surface 1140.

10
11 In Figure 35, the EHCU is locked to the tractor means by
12 the tractor locking mechanisms. The traction wheels of the
13 tractor means drags the EHCU into the flowline. After the
14 EHCU reaches a particular distance Z35 away from the XMas
15 Tree, then the traction wheels are turned off. The legend
16 Z35 is defined in Figure 35. Thereafter, the tractor locking
17 mechanisms are released, and the traction wheels of the
18 tractor means are retracted into the body of the tractor.
19 The tractor means is then pulled out of the well by pulling
20 on the wireline 1128. The EHCU is left installed in place
21 within the flowline. Not shown in Figure 35 are locking
22 mechanisms 1122 and 1123 on the EHCU which will lock it in
23 place within the flowline during production operations.
24 In one preferred embodiment, produced oil and gas flows
25 through the interior of the EHCU 1141 to the surface. In
26 another preferred embodiment, produced oil and gas flows
27 through the region between the inside diameter of the
28 flowline and the outside diameter of the EHCU that is
29 region 1142 in Figure 35. In yet another embodiment, the
30 production can flow through both regions 1141 and 1142.
31

32 In Figure 36, steel cased well 1144 is located within a
33 geological formation 1148 that penetrates the sea bottom 1152
34 at location 1156. Steel cased well terminates in XMas Tree

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1 1160 having control means 1164. Steel flowline 1168 is
2 attached to the XMas Tree and rests on the bottom of the
3 sea until location 1172 at which point it raises towards
4 the upper end of the flowline, which is riser 1174, that
5 is connected to Floating Production, Storage and Offloading
6 (FPSO) ship 1176.

7
8 The Pump-Down Conveyed Flowline Immersion Heater
9 Assembly ("PDCFIHA") is generally shown as element 1180 in
10 Figure 36. A portion of this apparatus includes an
11 Electrically Heated Composite Umbilical ("EHCU") 1184.
12 Hydraulic pressure P in the annular space between the inside
13 diameter of the flowline and the outside diameter of the
14 EHCU, which space is designated by numeral 1188 in Figure 36,
15 applies a force F to the hydraulic seals 1192 attached to the
16 PDCFIHA. Three seals are shown in Figure 36 which are
17 collectively labeled as element 1192 in Figure 36. The
18 hydraulic pressure P is used to carry the PDCFIHA into place
19 a distance Z_{36} away from the XMas Tree. The legend Z_{36} is
20 defined in Figure 36.

21
22 If the control means 1164 has closed a valve connecting
23 the flowline to the XMas Tree, then the displaced fluid from
24 annular region 1196 must go somewhere. A downhole pump motor
25 assembly is generally shown as element 1200 in Figure 36
26 which is very similar to that shown in Figure 8 herein. So,
27 the detailed elements of the downhole pump motor assembly
28 will not be labeled in the interests of simplicity. However,
29 this downhole pump motor assembly possesses hydraulic pump
30 1204 that energized by electrical motors 1208 and 1212.
31 Crude production flows into orifice 1214 of the hydraulic
32 pump, and exits from the orifices collectively identified
33 with numeral 1216 in Figure 36. This exiting fluid is
34 trapped within pump shroud 1220 that is attached to the EHCU

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1 at location 1224. Electrical power and control signals are
2 provided by internal conductors and/or fiber optic cables
3 within the walls of the EHCU, are broken out of the wall of
4 the EHCU by apparatus 1228 that provides power and control
5 signals to the downhole pump motor assembly by jumper 1232.
6 The fluid then flows through the pump shroud and then through
7 the EHCU towards the upper portion of the EHCU 1236 that is
8 connected to the FPSO ship. If the volume produced by the
9 hydraulic pump "V35P" exceeds the volume "V35D" displaced by
10 the downward movement of the PDCFIHA, then the PDCFIHA can
11 proceed into the well.

12

13 Even if the control means 1164 allowed the valve from
14 the flowline to the cased well to remain open (said valve is
15 not shown in Figure 36 for simplicity), as long as V35P
16 exceeds the volume V25D, then no fluid will flow back into
17 the steel cased well. FPSO ship is located in ocean 1240
18 having ocean surface 1244.

19

20 **Figure 37** is very similar to Figure 36, except here
21 the host is floating platform 1248. All the other numerals
22 in Figure 37 have already been otherwise identified and
23 described in Figure 36.

24

25 In **Figure 37A**, all the numerals have been defined except
26 those described in the following within this paragraph.
27 Locks 1221 and 1222 serve to lock the "PDCFIHA" into place
28 after it has been pumped down into the well. In one
29 preferred embodiment, cross-over valve 1249 allows fluid
30 flowing in region 1250 between the downhole pump motor
31 assembly 1200 and the pump shroud 1220 to be directed into
32 annular region 1188. Then production would flow through
33 annular region 1188 to the surface. In yet another
34 embodiment of the invention, the cross-over valve 1249 would

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1 allow fluid to not only flow through annular region 1128 to
2 the surface but fluid would also be allowed to flow in the
3 inside of the EHCU 1251 in that portion of the EHCU that is
4 between the floating platform and cross-over valve 1249.
5 In yet another embodiment, the cross-over valve 1249 may be
6 chosen to direct production to region 1251 only; to region
7 1184 only; and to regions 1251 and 1184 simultaneously.
8 After the locks 1221 and 1222 are deployed, the hydraulic
9 pump 1204 may be used to assist well production by providing
10 artificial lift.

11

12 In Figure 38, all the elements having numerals less than
13 280 have been described in relation to Figure 9 herein.
14 However, casing 274 in Figure 38 may also include other forms
15 of tubulars, including tubing. Open hole completion 1252 in
16 a reservoir with heavy oil 1256 causes heavy oil 1260 to flow
17 through expanded screen 1262 into the open hole 1264. Heavy
18 oil flows into the inflow assembly 1268, thorough intake
19 orifice 1272, into hydraulic pump 1276, and out exhaust
20 orifices that are collectively labeled with 1280 in
21 Figure 38. Electric motors 1284 and 1288 provide the power
22 to drive the hydraulic pump. After the heavy oil emerges
23 from the exhaust orifices, it is trapped by shroud 1292 that
24 is connected to Electrically Heated Composite Umbilical
25 ("EHCU") 1296. The annular region inside the shroud open to
26 fluid flow is defined by numeral 1294. The heated production
27 proceeds through the inside of EHCU 1298 towards the top of
28 the EHCU 1300 attached to platform 258. Electrical power and
29 control signals are provided to the electric motors by
30 electrical conductors and by fiber optic fibers within the
31 wall thickness of the EHCU. The hydraulic pump provides
32 artificial lift to the heavy oil produced.

33

34

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1 The Electric Flowline Immersion Heater Assembly
2 ("EFIHA") is generally designated with element 1304 in
3 Figure 38 which includes the Electrical Heated Composite
4 Umbilical 1296. In this case, hydraulic pressure P applied
5 at the platform in the annular region between the outside
6 diameter of the EHCU and the inside diameter of the casing
7 274, which is region 1308, provides a force on seals 1312
8 that forces the EFIHA down into the well. Guides 1316 help
9 centralize the EFIHA. As the EFIHA is forced downhole, a
10 certain displaced fluid volume V38D could be forced back into
11 formation which could damage the formation. However, if the
12 hydraulic pump forces a volume V38P into the EHCU, then
13 provided that V38P is greater than V38D at all times, then no
14 fluid is forced back into the open hole. This is important
15 to prevent formation damage from "back flow".
16

17 In one of the preferred embodiments above, fluid flow
18 from the open hole 1264 is caused to flow through region 1294
19 and then through the interior of the EHCU 1290 to the
20 surface. As described above, a cross-over valve can be
21 installed that will allow production to flow instead through
22 region 1308 to the surface. And yet another embodiment would
23 allow production to flow through both regions 1298 and 1308
24 to the surface.
25

26 The EHCU provides heat to reduce the viscosity of the
27 heavy oil produced from the open hole. Therefore, the
28 artificial lift provided by the hydraulic pump is used
29 efficiently to produce heavy oil.
30

31 Figure 39 shows an exploratory well with large volume
32 fluid sampling capability. Figure 39 shows a floating
33 platform 1320 with a small separator with fluid storage 1324
34 in ocean 1328 having ocean surface 1330. Marine blowout

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1 preventer ("BOP") 1332 is shown on ocean bottom 1336 at
2 location 1340. Borehole 1344 penetrates a first geological
3 formation 1348, a second geological formation 1352, and a
4 third geological formation 1356 in earth 1360. Casing 1364
5 penetrates the BOP and lines the borehole down to location
6 1368. Perforations 1370 were made into producing intervals
7 in the first geological formation 1348. Downhole sampling
8 unit shown as element 1372 in Figure 39 possesses an open
9 hole packer, with a sand screen filter, and a pump. The pump
10 is used to pump samples up insulated and heated coiled tubing
11 1376 through the casing to the small separator with fluid
12 storage 1324 on the floating platform. Perforations 1380
13 were made into intervals to be tested in second geological
14 formation 1352. In a preferred embodiment, electrical power
15 to operate the pump is obtained from electrical wires that
16 are in the wall thickness of an umbilical as described
17 earlier. On another preferred embodiment the heated tubing
18 is comprised of an Electrical Heated Composite Umbilical
19 (EHCU) as previously described above.

20

21 In relation to Figure 39, heated coiled tubing that is
22 pumped will allow large reservoir fluid samples to be
23 collected without the expense of a downhole completion. In
24 an emergency, the coiled tubing is cut at the marine BOP and
25 the downhole pump shuts in the coiled tube to prevent a
26 blowout path. Applications include areas with soft sandstone
27 and areas where larger fluid volumes are required to
28 determine the reservoir production fluid properties.

29

30 **Figure 40** shows an apparatus that provides power to
31 upstream functions. In preferred embodiments, this would
32 apply to subsea systems that are external to a flowline.
33 In Figure 40, flowline 1384 is in the vicinity of a subsea
34 installation 1388 that requires electrical power. Composite

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1 umbilical 1392 is attached to first assembly 1396. Composite
2 umbilical 1392 possesses electrical wires within its wall
3 thickness that are broken out by assembly 1400 that is
4 connected to jumper 1404. The electrical power is used to
5 energize electric motor 1408 that is used to energize
6 Progressing Cavity Pump 1412. As has been described in
7 relation to other embodiments above, pressure provided by an
8 external source in the annular region between the outside
9 diameter of the composite umbilical and the inside diameter
10 of the flowline acting on hydraulic seal 1416 forces the
11 entire apparatus collectively called the "Connector
12 Apparatus" 1420 into the flowline. The annular region
13 between the outside diameter of the composite umbilical and
14 the inside diameter of the flowline is defined as element
15 1386 in Figure 40. As previously described, the Progressing
16 Cavity Pump, in conjunction with seals 1424, is used to pump
17 displaced fluid through channel 1428 into the interior of the
18 composite umbilical 1432 for return to the surface. Landing
19 and locating shoulder 1436 is used to provide electrical
20 power to the flowline penetrating connector 1440. Subsea
21 power cable 1444 is attached to the flowline penetrating
22 connector 1440. The flowline penetrating connector 1440 is
23 placed into its proper position 1448 by an ROV. In various
24 different embodiments, the flowline is penetrated for
25 electrical, chemical and hydraulic power. This approach
26 minimizes umbilical costs to small installations.
27

28 **Figure 41**, all the elements through element 506 have
29 been defined previously. In addition, two of the
30 electrically insulated wires 1452 and 1456 are used to
31 uniformly electrically heat composite umbilical 1460 in
32 Figure 41.

33
34

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1 **Figure 42** shows one embodiment of a first resistor
2 network used to electrically heat composite umbilicals.
3 Here, wires 1452 and 1456 have uniform resistance per unit
4 length. The total resistance of each one of these
5 electrically insulated wires is $R(42)$ in ohms. These wires
6 are connected together at the lower end of the composite
7 umbilical shown by electrical jumper 1464. The total length
8 of each wire in the composite umbilical is $L(42)$, a legend
9 that is defined on Figure 42. The legend $V(42)$ in Figure 42
10 shows the voltage $V(42)$ applied uphole to the resistive
11 network. This first resistive network will result in uniform
12 heating of the electrically heated composite umbilical.
13

14 In **Figure 43**, all the elements through elements 506 have
15 been define previously. In addition, two of the electrically
16 insulated wires 1468 and 1472 are used to nonuniformly heat
17 composite umbilical 1476.
18

19 **Figure 44** shows an embodiment of a second resistor
20 network used to nonuniformly electrically heat composite
21 umbilicals. Here, wire 1468 does not have a uniform
22 resistance per unit length. In Figure 44, wire 1472 has
23 uniform resistance per unit length (but in other embodiments,
24 this need not be the case). Wires 1468 and 1472 are
25 connected together at the lower end of the composite
26 umbilical by a short electrical jumper 1480 having negligible
27 electrical resistance. The length of the electrically heated
28 composite umbilical is $L(44)$ and that legend is defined in
29 Figure 44. Wire 1472 has a uniform resistance per unit
30 length, and has a total resistance in ohms of $R(44D)$, a
31 legend that is defined in Figure 44. Wire 1468 has a
32 resistance in ohms of $R(44A)$ during a first length $L(44)/3$;
33 has a resistance in ohms of $R(44B)$ during a second length
34 $L(44)/3$; and has a resistance in ohms of $R(44C)$ during a

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1 third length of L(44)/3. The legends R(44A), R(44B), and
2 R(44C) are defined in Figure 44. Many ways may be used to
3 fabricate wire 1468, including suitably joining together
4 different sections of different wires having different
5 resistances per unit length, but otherwise having the same
6 outside diameters of insulation. The legend V(44) in
7 Figure 44 shows the voltage V(44) applied uphole to the
8 resistor network. The total resistive load is the sum of
9 R(44A), R(44B), R(44C), and R(44D). If R(44C) is greater
10 than R(44B); and if R(44B) is greater than R(44A); and if
11 R(44A) is greater than R(44D); then the electrically heated
12 composite umbilical will preferentially apply more electrical
13 heat to the lower (right-hand side) of the umbilical in
14 Figure 44. This nonuniform electrical heating has many
15 advantages including the application of heat in poorly
16 insulated areas of an umbilical or coiled tubing; the
17 matching of required heat to the transportation process of
18 hydrocarbons within the umbilical or coiled tubing to
19 avoid the build up of waxes and hydrates such as the
20 preferential heating of areas where high J-T cooling may
21 exist; etc.

22
23 **Figure 45** shows another preferred embodiment of the
24 electrically heated umbilical that is labeled with numeral
25 1484 that is an armored electric cable umbilical. Steel or
26 synthetic armor 1488 surrounds filler 1492 that encapsulates
27 electrical wires 1496 surrounded by electrical insulation
28 1500. This preferred embodiment can include certain types of
29 logging cables. The wires may be individual wires, pairs,
30 bundles, etc. The cable may have some wires dedicated to
31 communication, some for power and fiber optic fibers (not
32 shown in Figure 45) for communication and sensor service.
33 For heating the production (besides losses due to routine
34 power transmission losses) circuits may be dedicated to

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1 heating applications as described earlier. Sections of the
2 circuits may be designed for heating, thus the heat can be
3 directed to specific locations along the umbilical length as
4 described in other embodiments above.

5

6 Figure 46 shows another preferred embodiment of the
7 electrically heated umbilical generally designated as element
8 1504. The umbilical is surrounded by steel coiled tubing
9 1508 having any desirable outside diameter and having any
10 desirable wall thickness. Electric cable 1512 provides
11 electrical power for devices, provides communication service,
12 and provides electrical power for electrical heating of
13 fluids within region 1516 of the coiled tubing which may be
14 retrofitted into the steel coiled tubing to be replaced or
15 repaired. To replace cable 1512 after the steel tubing was
16 installed into a flowline, it may be pulled out of the steel
17 tubing leaving the steel tubing within the flowline. Then a
18 hydraulic seal between the outside diameter of the cable and
19 the inside diameter of the steel coiled tubing allows
20 hydraulic pressure introduced into that annular area to be
21 used to force down the cable into the steel coiled tubing.
22 The outside diameter of electric cable is dependent upon the
23 application for which it is chosen. In one preferred
24 embodiment, hot fluid is circulated down region 1516 and the
25 umbilical is used as an immersion heater. In another
26 preferred embodiment, electric current goes down the electric
27 cable and is conducted back up the coiled tubing that
28 provides immersion heating. In yet another embodiment, all
29 the heating comes from the power dissipated within electrical
30 circuits within the electric cable. In yet other preferred
31 embodiments, cable 1512 may also contain fiber optic cables,
32 hydraulic tubes, etc. for other applications.

33
34

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1 **Figure 47** shows yet another embodiment of the
2 electrically heated umbilical 1520 that is similar to that
3 shown in Figure 46, except here an extra thermal insulation
4 layer 1524 is bonded to the outside of the steel coiled
5 tubing. Umbilical 1520 is a thermally insulated umbilical
6 with an electric cable. Here, the electric cable includes
7 wires for heating the pipe, wires for control and power of a
8 downhole electric pump, and fiber optic cables for measuring
9 distributed temperature.

10
11 **Figure 48** shows yet another embodiment of the
12 eclectically heated umbilical 1528 that is called a bundled
13 umbilical. Outer wear sheath 1532 surrounds filler or
14 potting material 1536 which surrounds one or more electric
15 cables 1540. Each such electric cable provides functions
16 described in the previous paragraph. In addition, the
17 potting material surrounds one or more tubes 1544 having
18 channels 1548. The tubes may carry any fluid or chemical to
19 the end of the umbilicals. For example, these fluids may
20 include an emulsion breaker that is injected just upstream of
21 a pump. The electric cables provide power and communication,
22 and may provide distributed electrical heating. The filler
23 binds the umbilical together and provides for control of the
24 buoyancy of the umbilical.

25
26 Figures 28 and 29 show existing flowlines installed in a
27 producing oil field. Any of the Electric Flowline Immersion
28 Heater Assemblies shown in Figures 30, 31, 32, 33, 34, 35, 36,
29 37, and 37A may be retrofitted into existing flowlines. The
30 Electric Flowline Immersion Assemblies shown in these figures
31 are different embodiments of "electric flowline immersion
32 assembly means". Therefore, the "Electric Flowline Immersion
33 Heater Assembly" ("EFIHA"), the "Electric Flowline Immersion
34 Heater Assembly with Wireline Smart Shuttle" ("EFIHAWWSS"),

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1 the "Smart Shuttle Conveyed Electric Flowline Immersion
2 Heater Assembly ("SSCEFIHA"), and the "Pump-Down Conveyed
3 Flowline Immersion Heater Assembly" ("PDCFIHA"), are all
4 different embodiments of "electric flowline immersion
5 assembly means".

6
7 In accordance with the preferred embodiments herein, any
8 of the Electrically Heated Composite Umbilicals shown in
9 Figures 30, 31, 32, 33, 34, 35, 36, 37, and 37A may be
10 retrofitted into existing flowlines which are different
11 embodiments of "electrically heated composite umbilical
12 means" which are used to make "immersion heater means".
13 In accordance with the preferred embodiments herein, the
14 additional types of electrically heated umbilical immersion
15 heaters shown in Figures 41, 43, 45, 46, 47, and 48 may be
16 suitable retrofitted into existing flowlines and they are
17 different preferred embodiments of "electrically heated
18 umbilical means" that are used to make "immersion heater
19 means".

20
21 Any of the umbilical conveyance means shown in
22 Figures 30, 31, 32, 33, 34, 35, 36, 37, and 37A may be used
23 to install any of the "electrically heated umbilical means"
24 or the "electrically heated composite umbilical means" into a
25 flowline to make "immersion heater means". As described in
26 the preferred embodiments, these are installed with different
27 embodiments of "electric flowline immersion assembly means"
28 which provide different means to install, or remove, the
29 electric flowline immersion assembly means from the well.
30 Any means that is used to convey into a flowline, or remove
31 from a flowline, any "electrically heated umbilical means"
32 shall be defined herein as a "conveyance means to install an
33 electrically heated umbilical means in a flowline". Any
34 means that is used to convey into a flowline, or remove from

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1 a flowline, any "electrically heated composite umbilical
2 means" shall be defined for the purposes herein as a
3 "conveyance means to install an electrically heated composite
4 umbilical means".

5
6 It is important to be able to retrofit such electrically
7 heated immersion heater systems into existing flowlines for
8 many reasons that includes the following:

9 (a) to introduce an immersion heater system into an
10 existing flowline that was not expected to have wax or
11 hydrate build-up problems;

12 (b) to have repair alternatives for previously
13 installed, but failed, permanent heating systems; and

14 (c) to have operating flexibility to adapt the
15 production system to different production characteristics
16 from original expectations.

17
18 Electrically heated immersion heater systems can be
19 installed to prevent waxes and hydrates from forming.
20 Hydrates are a solid ice-like materials typically composed of
21 water and low molecular weight gases such as methane.
22 Hydrates form in high-pressure, low temperature, environments
23 such as those found in subsea production systems. Hydrates
24 may easily plug production systems, especially during
25 transient operating conditions if not properly managed.

26
27 In many of the preferred embodiments, a pump is
28 installed in the flowline and may be used in combination with
29 the electrically heated immersion heater system, which has
30 many advantages, including the following:

31 (a) such methods and apparatus increases the production
32 recovery rate helping the field's net present value ("NPV");
33 and

34

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1 (b) such methods and apparatus increases the total
2 recoverable reserves from the reservoir by reducing the
3 backpressure on the reservoir.

4

5 The installation of an electrically heated immersion
6 heater system in a flowline heats up any produced heavy oils
7 which reduces the viscosity of the produced heavy oils, which
8 has many advantages, including the following:

9 (a) such methods and apparatus reduces the pumping
10 energy required to transport produced hydrocarbons through
11 the flowline which therefore reduces the costs of producing
12 the hydrocarbons;

13 (b) such methods and apparatus makes some presently
14 non-commercial fields economic to develop; and

15 (c) such methods and apparatus allows for the efficient
16 subsea transportation of typical gelling crude oils.

17

18 In many of the preferred embodiments described,
19 nonuniform heating may be applied to the flowline(s) by the
20 electrically heated immersion heater system which provides
21 many advantages, including being able to configure the
22 production facility to better match and manage the thermal
23 requirements for heating of the flowline(s) to avoid build up
24 of waxes and hydrates, and to reduce the cost of producing
25 hydrocarbons from the reservoir.

26

27 Other preferred embodiments provide for the dynamic
28 reconfiguring of the heat supplied by an electrically heated
29 umbilical after the umbilical is installed into a flowline.
30 As an example of such a preferred embodiment, the value of
31 R(44C) in Figure 44 can be selectable, and controlled from a
32 surface computer. There are a variety of means for doing so,
33 including computer controlled switches in the wall of an
34

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1 Electrically Heated Composite Umbilical that can be used to
2 switch in, or out, certain resistor circuits.
3

4 Yet other preferred embodiments provide for the dynamic
5 reconfiguring the buoyancy of an electrical heated umbilical.
6 For example, computer controlled valves may distribute
7 different densities of fluids within one or more fluid
8 channels located within the wall of an Electrically Heated
9 Composite Umbilical. Such systems are described in detail in
10 Provisional Patent Application Number 60/432,045, filed on
11 December 8, 2002, and in U.S. Disclosure Document
12 No. 531,687 filed May 18, 2003, entire copies of which are
13 incorporated herein by reference.

14
15 In many of the preferred embodiments described, the
16 electrically heated immersion heater system may be removed
17 from the well, repaired, and retrofitted in the flowline
18 without removing the flowline which provides many advantages,
19 including the following:

20 (a) such methods and apparatus saves significant
21 operating costs by performing both the heater and artificial
22 lift pump service from the host facility without having to
23 mobilize a subsea intervention vessel; and

24 (b) such methods and apparatus allows for the use of
25 conventional electric submersible pumps for critical subsea
26 "tie-back services" to the host.

27
28 The term "tie-back service" has been used above.
29 Satellite production wells are frequently used to develop
30 small fields surrounding an existing facility to which they
31 are connected, and from which they are controlled. These
32 satellite wells provide tie-back service to the host
33 production facility.

34

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1 In view of the above disclosure, a preferred embodiment
2 of the invention is an apparatus comprising an electrically
3 heated composite umbilical means installed within a subsea
4 flowline containing produced hydrocarbons as an immersion
5 heater means to prevent waxes and hydrates from forming
6 within the flowline and blocking the flowline, whereby the
7 electrically heated composite umbilical means possesses at
8 least one electrical conductor disposed within the composite
9 umbilical means that conducts electrical current that is used
10 to heat the electrically heated composite umbilical means
11 within the subsea flowline.

12

13 In view of the above disclosure, a preferred embodiment
14 of the invention is a method of installing an electrically
15 heated composite umbilical means within a previously existing
16 subsea flowline containing produced hydrocarbons to make an
17 immersion heater means to prevent waxes and hydrates from
18 forming within the flowline and blocking the flowline.

19

20 In view of the above disclosure, a preferred embodiment
21 of the invention is a method of using an umbilical conveyance
22 means to convey into an existing subsea flowline possessing
23 produced hydrocarbons an electrically heated composite
24 umbilical means used as an immersion heating means to prevent
25 waxes and hydrates from forming within the flowline and
26 blocking the flowline.

27

28 In view of the disclosure above, a preferred embodiment
29 of the invention is a method of using an umbilical conveyance
30 means to convey into an existing subsea flowline containing
31 produced hydrocarbons an electrically heated umbilical means
32 used as an immersion heating means to prevent waxes and
33 hydrates from forming within the flowline and blocking
34 the flowline.

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1 In view of the above, a preferred embodiment of the
2 invention is a method of providing artificial lift to
3 produced hydrocarbons within a subsea flowline comprising at
4 least the steps of:

5 (a) attaching a progressing cavity pump to an electric
6 motor to make an electrically energized pump;

7 (b) attaching the electrically energized pump to
8 to a first end of a tubular composite umbilical possessing a
9 multiplicity of electrical conductors within the wall of the
10 tubular composite umbilical;

11 (c) conveying into the flowline the electrically
12 energized pump attached to the first end of the composite
13 tubular umbilical;

14 (d) using first and second of a multiplicity of
15 electrical conductors to electrically heat the composite
16 umbilical to prevent waxes and hydrates from blocking the
17 flow of the produced hydrocarbons within the flowline; and

18 (e) using at least third and fourth electrical
19 conductors of the multiplicity of electrical conductors to
20 provide electrical energy to the electrically energized pump,
21 whereby the progressing cavity pump provides artificial lift
22 to the produced hydrocarbons within the subsea flowline.

24 In view of the above, a preferred embodiment of the
25 invention is a method of providing artificial lift to
26 produced hydrocarbons within a subsea flowline comprising at
27 least the steps of:

28 (a) attaching a hydraulic pump to an electric motor to
29 make an electrically energized pump;

30 (b) attaching the electrically energized pump to
31 to a first end of a tubular composite umbilical possessing a
32 multiplicity of electrical conductors within the wall of the
33 tubular composite umbilical;

34

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1 (c) conveying into the flowline the electrically
2 energized pump attached to the first end of the composite
3 tubular umbilical;

4 (d) using first and second of the multiplicity of
5 electrical conductors to electrically heat the composite
6 umbilical to prevent waxes and hydrates from blocking the
7 flow of the produced hydrocarbons within the flowline; and

8 (e) using at least third and fourth electrical
9 conductors of the multiplicity of electrical conductors to
10 provide electrical energy to the electrically energized pump,
11 whereby the electrically energized pump provides artificial
12 lift to the produced hydrocarbons within the subsea flowline.
13

14 In yet another preferred embodiment of the invention, an
15 electrical heated composite umbilical means dissipating in
16 excess of 60 kilowatts of electrical energy to heat produced
17 hydrocarbons is installed within a flowline to prevent the
18 formation of waxes and hydrates and blockage of the flowline.
19

20 In another preferred embodiment of the invention, an
21 electrical heated umbilical means dissipating in excess of 60
22 kilowatts of electrical energy to heat produced hydrocarbons
23 is installed within a flowline to prevent the formation of
24 waxes and hydrates and blockage of the flowline.
25

26 In yet another preferred embodiment of the invention,
27 electrically heated composite umbilicals are approximately
28 neutrally buoyant within the fluids present within the
29 flowlines to reduce the frictional drag on the neutrally
30 buoyant umbilicals when they are installed into the
31 flowlines.

32 Still further, in yet another preferred embodiment of
33 the invention, electrically heated umbilicals are
34

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1 approximately neutrally buoyant within the fluids present
2 within the flowlines to reduce the frictional drag on the
3 neutrally buoyant umbilicals when they are installed into
4 the flowlines.

5
6 In another preferred embodiment of the invention, fluid
7 filled electrically heated composite umbilicals are
8 approximately neutrally buoyant within the fluids present
9 within the flowlines to reduce the frictional drag on the
10 neutrally buoyant umbilicals when they are installed into
11 the flowlines.

12
13 In yet another preferred embodiment of the invention,
14 fluid filled electrically heated umbilicals are approximately
15 neutrally buoyant within the fluids present within the
16 flowlines to reduce the frictional drag on the neutrally
17 buoyant umbilicals when they are installed into the
18 flowlines.

19
20 And finally, another preferred embodiment of the
21 invention is using the methods and apparatus to drill and
22 complete boreholes for infrastructure purposes such as for
23 water, sewer, electric power, and communications facilities
24 in metropolitan areas, and for subterranean pipelines in
25 other suitable locations.

26
27 While the above description contains many specificities,
28 these should not be construed as limitations on the scope of
29 the invention, but rather as exemplification of preferred
30 embodiments thereto. As have been briefly described, there
31 are many possible variations. Accordingly, the scope of the
32 invention should be determined not only by the embodiments
33 illustrated, but by the appended claims and their legal
34 equivalents.

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